DOCUMENT RESUME

ED 143 501 SE 022 891

AUTHOR	Maddock, M. N., Ed.; Power, Colin N., Ed.
TITLE	Research in Science Education, Volume 6. Proceedings of the Annual Conference of the Australian Science Education Research Association (7th, The University of Newcastle, New Scuth Wales, May 17-19, 1976).
INSTITUTION	Australian Science Education Research Association.
PUB DATE	76
NOTE	142p.; For Volume 5, see SE 022 850
EDRS PRICE	MF-$0.83 HC-$7.35 Plus Postage.
DESCRIPTORS	*College Science; *Conference Reports; *Educational Research; *Elementary School Science; Elementary Secondary Education; Higher Education; Instruction; Science Education; Science Teachers; Secondary School Science
IDENTIFIERS	Australian Science Education Research Association; *Research Reports

ABSTRACT

This volume contains papers presented at the seventh Annual Conference of the Australian Science Education Research Association held at the University of Newcastle in May, 1976. Paper topics include: undergraduate research experience for future teachers, programmable calculator effects on attitude towards physics, development of science concepts in children, science and perception, relationships between classroom environments and outcomes, logical connectives in science, classroom climate, and an examination of relationships between cognitive preferences, field-independence and level of intellectual development. (SL)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

ED143501

RESEARCH
IN
SCIENCE
EDUCATION

Volume 6

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

Colin N. Power

Australian Science Education Research Association

RESEARCH

IN

SCIENCE EDUCATION

VOLUME 6

Proceedings of the Seventh Annual Conference of the Australian Science Education Research Association, The University of Newcastle, NSW, May 17 - 19, 1976.

Edited by: *M.N. Maddock*

General Editor: *Colin N. Power*

AUSTRALIAN SCIENCE EDUCATION RESEARCH ASSOCIATION

All correspondence concerning this publication should be addressed to Dr. Colin N. Power, Department of Education, University of Queensland St. Lucia, 4067, Australia.

Copyright © 1976 by Australian Science Education Research Association.
Published by Australian Science Education Research Association.
Printed by the University of Queensland Printery.

CONTENTS

Page

Preface (v)

D.M. Hill and A.J.D. Blake
Undergraduate research experience for future teachers: A first effort 1

C.E. Engel
Audio tape programmes for individual study 6

R.B. Flanagan
Effect of a programmable calculator physics laboratory unit upon some attitudes to physics held by student science teachers 15

I.A. Napper
The development of science concepts in primary children by discovery strategies 27

J.E. Butler
Normal science and science education 45

Edward E. Nunan
Science and perception 51

Jeff. R. Northfield
The effect of varying the mode of presentation of ASEP materials on pupils' perceptions of the classroom 63

Richard T. White and Lindsay D. Mackay
The effect of science courses on perception of scientists and self 73

Colin Power and Royce Sadler
Non-linear relationships between measures of classroom environments and outcomes 77

Anthony J.D. Blake
An examination of relationships between cognitive preferences, field-independence and level of intellectual development 89

Contents - contd. **Page**

P. L. Gardner, L. Schafe, U. Myint Thein and R. Watterson

Logical connectives in science: Some preliminary findings 97

Barry J. Fraser

Classroom climate as predictor and criterion in science education research 109

R. Lewis

Victorian students: What happens to them after Higher School Certificate? 121

Contributors 140

PREFACE

The choice of the University of Newcastle as the venue of the 1976 7th Annual Conference of the Australian Science Education Research Association marked an important stage in the evolution of the association and set an important precedent. For the first time, the conference was held at a centre other than a state capital, and another provincial venue, the Riverina College of Advanced Education in Wagga, New South Wales, was chosen for the 1977 conference. Representation from the Colleges of Advanced Education was much stronger than at previous conferences, and the choice of one of these colleges for the venue in 1977 acknowledges this trend.

As has been the practice in the past, the papers published in this journal are the formal research papers presented during the conference. They represent a cross-section of the interests of researchers in the area of Science Education in Australia.

In addition to the formal research reports, the conference again provided "kite-flying" discussion papers, which have not been published here. Two of these papers challenged some fundamental issues. One paper presented a point of view that alternative paradigms to those usually used in traditional science exist, which science educators should acknowledge. Two of the formal papers were also philosophically based and challenged the assumptions underlying science in relation to the teaching of the subject in schools.

The Newcastle and District Science Teachers Association, in a "kite-flying" paper challenged the kind of research being carried out, claiming that much of it has little relevance for the classroom practitioner, and taking the researchers to task for making too little use of avenues of publication which reached the classroom teacher and could be readily understood by them.

In the final session of the conference, the question was again raised as to whether some of the formal papers presented really fitted the concept of science education research which had been originally fostered by the association.

The consensus of opinion reached was that diversity of interest was a good thing for the association, and was to be encouraged. It was also agreed that members of the association could give more attention to research relevant to classroom practice, and should seek avenues of publication which reached the practising teacher more readily.

The Australian Science Education Project again provided the stimulus for a significant proportion of the formal papers presented, primary science was again represented, and tertiary teaching in medicine and teacher training also provided research reports. However, there were no reports at all from the areas of the main science disciplines and other applied science subjects at University level, and response to notification about the conference to faculties and departments of this kind was very limited. Many academics in these disciplines have been rather vocal about what the schools do or do not do, such as the physics academic who once claimed to the editor that "The Wyndham Scheme has destroyed Physics in New South Wales".

While academics may be at the forefront in the search for knowledge in their own fields, many are archaic in their teaching approaches and ignorant of advances in the educational aspects of science. There is a need for wider representation from scientists interested in improving the quality of science education at tertiary level, and for scientists and educators to pursue research into science education problems at this level.

Despite this deficiency, the Newcastle conference can be regarded as a highly successful one. Thanks are expressed to all those people at the Newcastle College of Advanced Education, the University of Newcastle and Trans Australia Airlines who assisted in the organisation, with soecific thanks to co-executive officer Terry Sheedy for undertaking a lion's share of the work.

M.N. MADDOCK
The University of Newcastle
August 1976.

UNDERGRADUATE RESEARCH EXPERIENCE FOR FUTURE SCIENCE TEACHERS: A FIRST EFFORT

D.M. Hill and *A.J.D. Blake*

Introduction

In a recent paper, White (1976) expresses concern about the lack of liaison between teachers and educational researchers. He indicates that one solution to the problem may be to involve teachers more in the research process. Such a suggestion is in line with the rationale that has caused Riverina College of Advanced Education to include within the B.Ed. course for secondary science teachers a subject that introduces the prospective teacher to the nature and purposes of educational research. The first eight students were enrolled in this subject in 1975.

The subject focussed on the relationship between the classroom teacher and research. Emphasis was placed on action research as a basis for informed curriculum decision-making and it involved the students very substantially in the type of project which might reasonably be expected of a teacher. This paper describes the effectiveness of the experience as a means of influencing the new teacher's predisposition towards conducting action research in his classroom and in addition, it describes the outcomes of the actual research project.

Nature of the research project

The science education staff at Riverina college of Advanced Education have been concerned with the lack of trials of newer science curriculum projects in the area and considered the idea of carrying out such an investigation. It was decided to attempt to measure some of the possible outcomes of introducing a structured enquiry-based science programme in a local primary school. The Science Curriculum Improvement Study (SCIS) project was chosen and the Regional Education Director made funds available for the purchase of the SCIS materials. A local School Principal agreed to cooperate in the venture. He suggested that two year three classes which had been formed in a "more or less random fashion" from the pupils who had been in an open classroom in the previous year might be used. The Principal dissected the available data in an attempt to show that the two classes were comparable.

This situation provided a ready-made basis for the students' research. Furthermore, it had the additional advantage of causing future secondary science teachers to investigate the workings of a primary school and interact with primary school children. As a prelude to proceeding with the design and implementation of the project, the students were required to become familiar with the aims and rationale of the SCIS project and the context of the unit "Interactions and Systems". This unit concentrates on development of the concepts of *object, interaction, system* and *variable* and such skills as observing, classifying and identifying variables.

Consideration of the nature of this SCIS unit and a review of the literature relating to field trials of SCIS materials led the students to identify the sorts of outcomes which may be expected from the use of this unit in a classroom. A range of cognitive, attitudinal and personality variables were identified as legitimate dependent variables. Given that it was possible only to use the unit over a period of ten weeks, amounting to about 20 hours of classroom time, many of the proposed variables were quite unrealistic. However, it was decided to allow the students to proceed with measuring all the variables identified. This decision was taken because it gave the students useful experience in administration of a range of tests (and also in test construction) and it also provided some interesting data on a small sample of primary school children.

The students agreed upon the use of a conventional pre test-post test-control group design. The experimental group was the class which used the SCIS unit, the control group was the class which proceeded with the normal programme in science. Both classes were visited by the students during the conduct of the project and a set of tests was administered as a pre and post battery.

The tests administered were as follows:

1. a set of individually administered tasks based on Weber (1971) designed to test for skills and attitudes consistent with the rationale of the SCIS project, including observing, measuring, using space-time relationships, classifying and the use of rational explanation;
2. a set of tasks designed to measure the stage of cognitive development in a manner consistent with the Piagetian framework adopted by the SCIS project –
   - (a) conservation of continuous quantity,
   - (b) conservation of weight (Piaget and Inhelder 1941),
   - (c) seriation – based on observation of three blocks of unequal weights using an equal-arm balance designed by the students,
   - (d) combination thinking – a task involving students in determining what combination of switches caused a light to go on or off, developed as an analogue of Piaget's colourless chemicals test,
   - (e) moral judgement – questions involving the separation of outcome and intent – a factor which is related to the child's stage of intellectual development (Tomlinson-Keasey & Keasey (1974));
3. a group-administered measure of self-concept based on a test developed by D. Felker and communicated personally to the authors, included in the battery by the students because of the suggestion by Koocher (1974) that intellectual development is of central importance in self-concept development and anecdotal evidence from the School Principal which suggested that some of the pupils had poor self-concepts;
4. a multiple choice test designed to evaluate understanding of the basic concepts extant in the SCIS unit viz., *object, interaction, system* and *variable*, a test designed by the students and administered by the classroom teacher.

In addition to this battery of tests, on a non-science day at the end of the sixth week of teaching, pupils in both classes were asked by the classroom teacher to rate the eleven subject areas which they studied in order of preference. In a sense, this was a part-test only situation and the students were aware that it embodied the assumption that their two groups were identical with respect to their relative preference for science at the beginning of the experiment.

Experimental results

The mean gain-scores for experimental and control groups on the battery of tests is presented in the Table. Inspection of the table shows that both groups appeared to gain differentially on particular tests. However, the experimental group showed significant gains on the skill of observing ($F_{1,46} = 7.47$; $p < .01$) and on knowledge of concepts ($F_{1,46} = 4.80$; $p < .01$).

On the subject preference test given in the sixth week, the mean rank order for science on the 1-11 scale was 8.5 for the control group and 6.0 for the experimental group.

TABLE OF RESULTS

Average differences between pre- and post-test scores for experimental and control groups

Test	Average Gain-Scores Control (n = 21)	Experimental (n = 26)
Skills and Attitudes		
observing (5)	-0.237	+0.433
space time relationships (5)	+0.713	+0.310
measuring (5)	+0.762	+0.310
classifying A (3)	+0.381	0.000
classifying B (3)	+0.190	+0.423
rational explanation A (3)	-0.095	-0.115
rational explanation B (2)	+0.048	+0.039
Cognitive Development		
continuous quantity (3)	+0.048	-0.192
conservation of weight (3)	-0.048	+0.154
seriation (2)	-0.190	+0.192
combinatorial thinking (6)	+0.429	+0.963
moral A (3)	-0.048	-0.039
moral B (4)	+0.190	+0.270
Selfhood		
self concept	+1.802	+1.523
Knowledge		
concepts (4)	+0.190	+0.423

Maximum score in ( )

Discussion

The project highlighted for the students many of the difficulties and limitations of experimental classroom research. They had no option but to use existing classes with their teachers, hence the teacher variable was not controlled.

The project ran for only ten weeks and thus any long-term outcomes might have been missed. It is possible that the relatively higher preference for science in the experimental class could be due entirely to the enthusiasm of the teacher given an expensive set of resources and the novelty of the situation with the pupils. However the pattern of improvement suggests that this was not the case. While most differences are not statistically significant, the improvements in the experimental group over the control are consistent with the outcomes expected from the type of experiences generated by the SCIS materials. Thus improvements were to be expected in observing, classifying, seriation, combinatorial thinking and in understanding of the particular concepts. Such changes might well produce changes on measures of level of intellectual development. In other aspects which are not so directly related there is no such pattern of improvement in favour of the experimental group.

Discussion of the results cannot be limited to consideration of the statistical data. The students became aware that they had more information about the groups, particularly the experimental group, than was evident in the figures. The figures did not expose the enthusiasm for enquiry-based investigations shown by pupils who were non-achievers in more conventional classroom settings. Consequently, they were led to consider the possibility of more naturalistic forms of research activity as a more meaningful alternative for many situations requiring classroom-based research.

Conclusion

As a means of providing some insights into the research activity for future science teachers, the project was a qualified success. Throughout its inception and implementation there remained an uneasy compromise between conducting a piece of worthwhile research and providing the maximum possible range of experiences for the students undertaking the subject. The experience undoubtedly was valuable for the students, it provided them with insights which served as the bases for developing individual research proposals for the evaluation of a curriculum change in a secondary school. In general, though, the scope of the project was too ambitious for the time that was available and this led to a feeling of frustration, if not in the students, certainly in the authors.

The investigation itself suffered from obvious limitations which have been discussed above. However, the gains observed in favour of the class using SCIS materials are congruent with those identified by a four-year longitudinal study conducted by Renner et al. (1973) and suggest that a more rigorous investigation is warranted. It may be possible to engage our undergraduate students in a longitudinal study of the effectiveness of SCIS by involving different groups at different stages of the project. We believe that the first attempt has shown that it is a worthwhile component of pre-service teacher education.

References

KOOCHER, C.P. "Emerging selfhood and cognitive development." *Journal of Genetic Psychology*, **125**: 79-87, 1974.

PIAGET, J. and INHELDER, B. *Le Developement des Quantities Physique chez l'Enfant.* Delachaux et niestle, Neuchatel, 1941.

RENNER, J.W., STAFFORD, D.G., COFFIA, W.J., KELLOGG, D.H. and WEBER, M.C. "An evaluation of the Science Curriculum Improvement Study." *School Science and Mathematics* **73**(*4*): 291-318, 1973.

TOMLINSON KEASEY, C. and KEASEY, C.B. "The mediating role of cognitive development in moral judgement." *Child Development*, **45**: 291-298, 1974.

WEBER, M.C. "The influence of the Science Curriculum Improvement Study on the learner's operational utilization of science processes." Unpublished doctoral dissertation. University of Oklahoma, 1971, 64-76 quoted in J.W. Renner, D.G. Stafford & W.B. Ragan, *Teaching Science in the Elementary School,* second edition, Harper & Row, 1973.

WHITE, R.T. "Ivory tower and mud hut: Researcher and teacher." *Australian Science Teachers' Journal*, **22**(*1*), 55-60, 1976.

Acknowledgements

Appreciation is expressed for the assistance given to the students and to the authors by Mr. F. Brett, Regional Director of Education for the Riverina and by Mr. L. Irvine, Principal of Ashmont Public School. Thanks are extended to the students for the tolerance and enthusiasm which they displayed for the first attempt.

AUDIO TAPE PROGRAMMES FOR INDIVIDUAL STUDY

C. E. Engel

Although emphasis on individual and independent study has come to play an increasingly important role in higher education, remarkably little has been done to explore how technology might be harnessed to support these forms of learning. In medical education investigations have tended to concentrate on motion picture film (Engel, 1973), video tape (National Medical Audio Visual Center, 1969) and computer programmes (Conference on the Use of Computers in Medical Education, 1968). These are all relatively complex and expensive aids, both in their production and in their use. Although the printed word is still the most inexpensive and convenient means for individual study, little attempt has been made to improve the text book. In Britain, at least, the Open University and the Medical School of the University of Dundee are among the few institutions where significant efforts are made to apply the lessons learned from investigations with programmed learning (Leith, 1969) and information mapping (Horn, Nicol and Kleinman, 1969).

Between films, video tapes, computer programmes and the printed word is a technology of intermediate complexity and cost, the audio tape. The introduction of the Phillips "Compact" or "Type C" cassette has made the use of audio tape relatively inexpensive and more flexible in its application. While it is almost inevitable that early uses of a new technology will be based on past experience, few teachers seem to have progressed beyond producing tapes by reading lectures into a microphone. This situation has been aggravated by the prevalence of the "Oh my!" disease; "Oh my, isn't technology marvellous, the more complex it is, the more it will do the teaching for me". This state of mind has spawned a flood of programmes where 35 mm. transparencies are electronically synchronised with recorded lectures. A recent survey (Harris, 1976, pp. 136-140) lists no fewer than 14 different models of equipment specially marketed for the replay of such illustrated, recorded presentations. This use of audio tape seemed to us unnecessarily expensive, restrictive and unimaginative. However, on the basis of investigations we carried out over a period of six years at the B.L.A.T. Centre for Health and Medical Education, London, it was recognised that if audio tape were to be expected to do more than merely present recorded lectures, answers would have to be sought for a number of questions.

How should the information, that is to be transmitted, be prepared to maximise the potential advantages and minimise the disadvantages of learning by working with an audio tape?

Does individual learning with audio tapes have advantages, according to the level of studentship – whether first year undergraduate or mature postgraduate?

What, if any, are the advantages in different learning situations or learning tasks – other than the lecture?

How economically viable is the use of audio tape, in terms of equipment and materials and in terms of the time needed for production, when this is related to large numbers of students? Therefore, are such programmes transferable to other centres of learning?

Lastly, how practicable is this approach to learning? How easy is its use for students, and how easy is production and application for teachers?

Any survey of investigations into the educational use of media, such as film or television, shows that, in most instances, their protagonists look for clear advantages before they have learned how to use the medium (Geis, 1976, pp. 1-6). We, therefore, started by looking into the most appropriate methods for designing audio tape programmes in relation to learning by listening to recorded speech. We decided to concentrate on audio tape in cassettes with illustrated booklets. It was argued that booklets would be more flexible in their use than transparencies. Simple audio cassette playback equipment can be used anywhere, not just in expensively equipped study carrels, since projectors are only needed to make the tiny 35 mm transparency image big enough for the student to read.

After a great deal of trial and error, we evolved an approach which is summarized in Table 1. I would like to concentrate on steps 3 and 7 and then come back to steps 4 and 6. We have shamelessly borrowed from experience gained in experiments with programmed learning. So, for example, an attempt is made to start with an introduction that helps the student to appreciate why he should want to study a particular programme. At appropriate points in the script, problems or questions are inserted that encourage the student to use what he has heard. In other words, encourage him to participate actively in his own learning. All programmes also include a self-test device at the end. Here the student is encouraged to re-think all that he has learned. When he listens to the answers, he can find out how well he has succeeded and he is offered recapitulation in a new and thus non-boring manner. It also gives the teacher the opportunity to re-emphasize important points and to correct any possible misunderstanding.

TABLE 1

Construction of recording scripts

1. Specify what the student should be able to do as a result of studying with the programme.
2. Define progression of learning steps towards achieving the objective(s).
3. Write a first treatment, including notes, indicating the content of a motivating introduction, and notes outlining opportunities for student participation.
4. Define essential and subsidiary visual material.
5. Write the script, based on steps 3 and 4.
6. Prepare visual material.
7. Transcribe the script into the spoken language.

When the basic script has been agreed to, we deliberately transcribe it into the *spoken* language. Long sentences are broken down into shorter sentences. Indirect references, such as "*they* would therefore be expected to . . .", are replaced by the nouns to which they refer. While this can look awkward and repetitive in the script, the repeated use of specific nouns is quite unrecognised by the listener. We have applied this finding and use repetition in other ways in order to enhance familiarisation with the subject matter. We also ensure that the conditional part of a sentence comes at the end. This assists the student to orientate himself before he has to concentrate on the qualifying aspect of the information. Lastly, we loosen up the text and introduce a more personal and informal mode of address. Our purpose is twofold. First, we have found that intellectual indigestion results if every word conveys a message that must be absorbed. Second, we try to simulate as closely as possible, a situation where the student will feel that the tutor is speaking to him as an individual.

As for illustrations, some will be essential for a better understanding of the subject matter. Others will be useful in a supportive role. Yet others will ensure that the student will look at visual information that is related to what he hears. His attention would be distracted very rapidly, as soon as images and words to not relate to each other. Above all, an illustration must make its point immediately and in no way distract the student's attention; just imagine that the student is told to turn to the next page and sees a gorgeous bathing beauty on the beach -- while the discussion is concerned with an aspect of seashore biology.

One more point is perhaps worth making in relation to pictures when they are to illustrate a technique. Most teachers would perhaps choose a film or videotape, since, after all, a technique means movement. However, we have found that a sequence of simple sketches of the major steps may be much more helpful to the student. He can reorientate himself while he listens to advice and practices the maneouvres.

The illustrated booklet has a number of advantages in comparison with a set of slides, particularly for independent learning. From the booklet the student can scan the content, as well as the aims and objectives of the programme. He can use the statement of pre-requisites and the self-test to establish whether he should use a particular programme or not. He can use the blank page that separates one illustration from the next for his notes, so that he can use the booklet for subsequent reference and for revision. More recently, we have developed a simple modification to playback machines (Fewings and Wakeford, 1974, pp. 18-20), so that the student can hear signals as he runs the tape forward fast. In this way, he can select specific sections of a programme without having to work through the whole tape. This has proved to be particularly valuable for revision exercises that are designed to help the student to organise his body of knowledge and to establish what he has not remembered or not understood.

Our three main questions were: How acceptable, how effective and how efficient are illustrated audio tape programmes for individual learning? They were related to two specific sets of circumstances, as we also wanted to investigate the application of audio tapes for individual study at different levels of studentship, and in different learning situations or for different learning tasks. The latter included guidance in revision, guide to postgraduate study, integration of theory and practice, preparation for clinical responsibilities, and material that would stimulate interest in the subject to be studied. The details of the earlier experiments and results are summarised in our report to the funding body (B.L.A.T. Centre for Health and Medical Education, 1968-71) so that the remainder of this paper will only highlight one or two aspects.

Acceptability of such programmes by staff and students was investigated by interviews with teachers, by questionnaire with students (after Ellams, 1969), and by recording the use that was made of the programmes. The major objection by students referred to boredom where we had used the same voice for several programmes. However, even the most critical tended to indicate that they would recommend this approach to the next class of students. Teachers were ready to accept the materials as soon as they found out that they could amend the booklet and script, and re-record the tapes if they so wished.

Effectiveness was measured by testing for the attainment of the specified objectives. Two aspects may be of interest here. First, we did not use immediate post-tests but allowed approximately three months to elapse before testing the students. Our intention was to allow for natural decay in memory and for reinforcement of learning through other, subsequent learning opportunities – but these were not directly related to the content of our programmes. As might be expected, our results were not as outstanding as those normally achieved with immediate post-tests. However, we would argue that our approach is more realistic. Second, our test instruments varied according to the type of objective to be assessed. For example, we used the modified essay test (Knox, 1975) for a programme on the Management of Cardiac Arrest (Zorab, 1973) (Table 2). It will be clear that a multiple choice question paper would be inappropriate when the student is expected to demonstrate that he can make rapid decisions in an emergency situation where no one is available to offer him a choice from alternatives.

TABLE 2

Example of matching test instrument to learning objective

OBJECTIVES

FOR – The Resident House Officer

TO – Enable him under hospital ward conditions –

a) to diagnose cardiac arrest

b) to initiate and carry out cardiac massage and artificial ventilation

c) to initiate and assist at
    (i) improving ventilation
    (ii) E.C.G. interpreation
    (iii) drug therapy
    (iv) defibrillation

d) to check when resuscitation measures ought not to have been instituted

e) to assess when cardiac massage can cease.

MODIFIED ESSAY TEST

1. *SITUATION*

You are discussing a patient's notes with Sister when a nurse hurries in to say that Mr. Evans, a patient unknown to you, has suddenly collapsed in bed and has, she thinks, had a cardiac arrest.

QUESTION

List your actions over the next ½ to 1 minute.

Efficiency was assessed in a number of ways. Technicians and secretarial time occupied in handling the programmes for students proved to be small enough to be absorbed within their normal duties without any difficulty.

In order to reduce time required by teachers for programme design, we evolved a team approach (Table 3). While educational specialists would relieve the teacher of as much of the work as possible, the teacher remained the kingpin, as it were, and made all final decisions. For example, someone with a journalistic flair would transcribe the written script into the spoken language. Triple spaced typing enabled the teacher to make final corrections to ensure accuracy and correct emphasis. Even so, we found that "practice makes perfect", and teachers completed their part of the task more rapidly as they became more expert in this method of teaching.

Several of our collaborators have since continued this practice in their parent institution.

Although we have tended to use our authors to make the recording, we have found that this chore is not essential for student acceptability or effectiveness (Wakeford, 1972). However, student reactions make it advisable to use different voices for a series of programmes to avoid boredom.

TABLE 3

Team approach for division of labour

Step	Teacher	Team
Objectives	•	•
Learning Steps	•	•
Treatment	•	
Essential Visuals	•	
Intermediate Visuals		•
Script	•	•
Prepare Visuals		•
Transcribe Scripts		•

The average length of any one tape is twenty minutes, to allow for additional time spent on exercises, answering questions and listening to the correct replies. We have recorded the time spent by students on each programme. This varied between students but was never excessive. Indeed, in one comparative trial, we found that study by reading the equivalent text occupied more student time, without resulting in greater learning effectiveness (Engel, Irvine and Wakeford, 1972, pp. 311-316).

In another experiment, students were allowed to use the equipment and materials when and where they liked (Table 4). These were first year medical students studying embryology. We offered them five programmes on the causes and mechanisms of congenital abnormality. The aim was to investigate the application of audio tapes as an additional stimulus, to make embryology clinically more relevant. Not only did the students tend to use the programmes in the evenings and at weekends, but they also preferred to use them in their own rooms. This and other findings confirm our view that specially equipped carrels may be an unnecessary luxury.

Upkeep and maintenance were easy and inexpensive. The only losses reported were from student lockers in the absence of their owners.

Table 5 illustrates the calculation of the cost per student-study-session. This is in pounds sterling, but it amounts to approximately 27 cents per student-use of one programme. The biggest cost relates to the booklet. However, some teachers prefer to issue only a limited number and to collect them when students hand the cassettes of tape back again.

Once a set of programmes was found to be acceptable and effective, we undertook transfer experiments in order to see whether staff and students at other centres would also find the materials useful. In most instances, this has been confirmed. We have, therefore, made the programmes more widely available on the basis of partial copyright release. For the payment of a very small fee, the purchasing institution receives one copy of the recording script and one copy of the illustrated booklet with the right to make alterations, translate, record and prepare copies for use by its students for a period of three years. In order to protect the name of the original author, the title page of the booklet must include a statement indicating that the original has been altered. The copyright fee is shared among the authors.

TABLE 4

Choice of time and place for the use of additional study material

Generally, when did you use the tapes?

	(St. Thomas')	(Charing X)
During "office" hours	6%	8%
Evenings, weekends	94%	92%
n	36	35

Where did you listen to the tapes?

	(St. Thomas')	(Charing X)
In the hospital/medical school	6%	3%
At home	91%	94%
Other	3%	3%
n	36	35

In summary it is possible to say that our approach has been generally acceptable, effective and efficient. We have found that audio tapes with illustrated booklets can be useful for individual study in a number of ways; but, mainly, to offer students an alternative to learning from texts, and to provide a more appropriate input when the students' eyes and hands are already occupied — for example, during laboratory exercises or when studying with the microscope. However, we will not be able to eliminate the novelty effect until a sufficiently large series of programmes exists in any one subject. This, we hope, may soon be the case, when my former colleagues have completed their work on some 50 programmes with the Board of Studies in Physiology of the University of London.

TABLE 5

Calculation of cost of equipment and materials

		£ Sterling
11	Audio Tape Cassette Recorders with Earphones, Amortised Cost for One Term, Assuming a 5 Year Equipment Life	15.00
11	Copies of Each of 5 Programmes as cassettes, Assuming Two Uses per Year for 3 Years	5.50
95	Copies of Each of 5 Notebooks	66.50
1	Student Study Session	0.19

References

B.L.A.T. CENTRE FOR HEALTH AND MEDICAL EDUCATION. *Final report to the Nuffield Foundation: The development and evaluation of audio tapes with illustrative material for individual learning in medical education 1968-1971.* London, 1968-71.

CONFERENCE ON THE USE OF COMPUTERS IN MEDICAL EDUCATION. *Proceedings.* The School of Medicine, University of Oklahoma, Oklahoma City, 1968.

ELLAMS, J.J.P. "The development of a student attitude questionnaire for use in programmed learning investigations," in *Aspects of Educational Technology*, **2**, Methuen, London, 1969.

ENGEL, C.E., IRVINE, E. & WAKEFORD, R.E. "Report on the transferability of an individual learning system." *British Journal of Medical Education,* **6**: 311-316, 1972.

ENGEL, C.E. *Film in medical education – production and use.* Councils and Education Press, London, 1973.

FEWINGS, M.J. & WAKEFORD, R.E. "Adaptive programmes on audio-tape-branching tape. *Medical and Biological Illustration,* **24**(*1*): 18-20, 1974.

GEIS, G.L. "Trick or treatment". *Learning and Development,* (McGill University) **7**(*3*): 1-6, 1976.

HARRIS, P.R. "Slide and Filmstrip with synchronised sound." *BKSTS Journal,* **58**(*5*), 1976.

HORN, R.E., NICOL, E.H. & KLEINMAN, J.C. *Information mapping for learning and reference.* United States Air Force, Bedford Mass., 1969.

KNOX, J.D.E. *The modified essay question.* Association for the study of Medical Education, Dundee, 1975.

LEITH, G.O.M. *Second thoughts on programmed learning.* Councils and Education Press, London, 1969.

NATIONAL MEDICAL AUDIO VISUAL CENTER. *Towards improved learning.* U.S. Department of Health, Education and Welfare, 1969.

WAKEFORD, R.E. "Preparing audio tape recordings for individual study: Notes on the relative acceptability of different speakers." Medical and Biological Illustration, **22**(*1*): 13-14, 1972.

ZORAB, J. *The management of cardiac arrest,* Churchill Livingstone, Edinburgh, 1973.

EFFECT OF A PROGRAMMABLE CALCULATOR PHYSICS LABORATORY UNIT UPON SOME ATTITUDES TO PHYSICS HELD BY STUDENT SCIENCE TEACHERS

R. B. Flanagan

Introduction

There is no doubt that computers of various degrees of complexity are finding application in a huge number of fields. Not only people such as scientists who use computers feel the impact of the expansion of their use. Members of the general public are forming attitudes towards computer use, as they receive communications such as accounts, which are prepared with computer assistance. It was felt, therefore, that teachers of school physics should have experience with elementary applications and programming of computers. Their attitudes to computer use, and those which may be transmitted by them may thus be based, to a greater degree, upon personal experience.

It was also expected that such experience would have desirable effects upon the students' attitude to physics. This expectation is based upon personal experience of the author with computers and programmable calculators, as well as upon reports which frequently occur in the relevant literature. These reports of subjectively evaluated increases in enthusiasm during courses involving introduction to computer use, are referred to later in this paper.

It was decided therefore, that a five-week experimental physics laboratory unit involving the skill of writing programmes for a programmable calculator, should be devised to form part of the first year physics course for student science teachers at Newcastle C.A.E.

Apart from the desire to generate favourable attitudes to physics through stimulation of enthusiasm, there existed independently the desire to introduce students to some possible applications that computers could have in physics teaching. Sandery (1974) maintains that the only truly effective way to promote computer awareness is to have students use computers. He also points out that, if in addition to developing a balanced attitude towards computers, one can also use them to aid the students' understanding in science, then there is all the more reason for using them.

Shirer (1973), reports that in America, the Committee of Physics in Two-Year Colleges has approved by unanimous ballot the following position statement concerning the use of computers in physics teaching:

> The computer has been demonstrated to be an extremely useful and effective instrumental tool in lower division courses in physics, mathematics, engineering and many other academic areas. Adequate computer services therefore should be available to students and faculty in much the same way as library services.

The committee also maintained that Physics Faculty members have professional obligation to use computing services in their teaching whenever appropriate.

Slagle (1969), asserts that because computers' potential for use in teaching a given concept is not quickly apparent to inexperienced users, teachers should be introduced to computer programming.

Elmer (1969) claims that too often a science student hopes to deduce valid relationships between variables from too few experimental results. He maintains that this is far from the realities of scientific practice and that this situation is frustrating to conscientious students. Where calculation time prohibits the determination of a large number of values, the programmable calculator can alleviate this frustration.

Most of the related work reported in the literature refers to applications of computers. As access to computers is limited for the physics students under study, and may be limited for school children which they will teach, it was necessary to use a programmable calculator (Sharp Compet 364 p-III) instead of a computer.

It is assumed in this study that much of this literature on computers is of relevance to work with programmable calculators. In support of the use of such calculators, Craig (1974, p. 42) reported conducting simulation programmes for which Showalter had used a computer. Craig pointed out the added advantages of low cost.

Shirer (1973, p. 294), points out that desktop size calculators are available which can surpass many of the features of small computers. Magnetic card programme storage used by the calculator in the present study is more convenient than paper tape used with minicomputer Teletype terminals.

Although most high schools in the Newcastle area have programmable calculators, a survey conducted as part of this study indicates that very few science teachers use them. Only 9% of the science teachers at the 17 high schools surveyed, had written a programme for a programmable calculator. Dean (1975), suggests that the same problem exists in Britain. The results of this study provide some support for the argument that programmable calculators can be used to advantage in the more advanced high school physics work.

Physics courses have not been noted for their tendency to strengthen positive attitudes towards physics (MacKay, 1970). It is undesirable that innovations be made which will further reduce physics students' enjoyment of and interest in physics and physics courses. If it can be shown that some desirable attitude changes result from introduction of a desirable innovation, the probability that the innovation will be adopted in other courses should increase.

Thus it was decided to develop attitude scales in an attempt to detect relevant attitude changes which it was hypothesised could occur. A noteworthy feature of many studies relating to students' introduction to computer use in science courses is the high level of resulting student enthusiasm reported (Bongarzone 1970, Showalter 1970, Summerlin 1971, Craig 1974, Malpas 1974, Sandery 1974, Bligh 1974). These reports depended largely upon subjective evaluation, based upon observation, such as desire to use the computer much more often than the course required. Any evaluation of such enthusiasm was done with the use of informally constructed questionnaires.

MacKay (1970) and Gardner (1972) report the use of scales of attitudes to physics; but these could not be used in entirety, as some items would not be transferable to the population under study, and some attitudes of interest in this study were not included.

It was necessary therefore, to devise scales to detect possible changes in particular attitudes to physics, because no scales existed which were aimed at precisely this type of population and at the desired attitudes.

MacKay (1970) outlined a Likert-type scale for assessing enjoyment of physics, which was developed in a study of P.S.S.C. students. Two sample items given by MacKay were used as a guide in construction of items for an interest in physics scale for N.C.A.E. physics students.

The problem

The experimental group participated in a five week laboratory course involving experience with physics experiments which depend heavily upon the use of a programmable calculator. The purpose of this study was to determine the effect of this experience upon attitudes to physics which were held by the participants. The null hypotheses tested were that, at the end of the five week experimental period, there would be no significant difference between the scores of the experimental and control groups on the scales:

1. interest in conducting physics experiments,
2. interest in the study of physics in general,
3. confidence in own ability to master the use of complex equipment.

As no suitable attitude scales were already in existence, it was necessary to construct three 20 item scales, to detect changes in attitudes to physics, which experience with the programmable calculator experiment unit might be expected to produce.

Procedure

Sample and experimental design. The subjects used in this study were thirty-two Physics I students at Newcastle College of Advanced Education. All of these students were working toward the award of Diploma in Teaching and expected to be employed as science teachers on completing the diploma.

The students were assigned to the experimental or control group by a more or less random process, but, as for organisational reasons this could not be done using a table of random numbers, the groups could not be regarded as having been formed by truly random allocation. For this reason, a method of statistical analysis which accounted for effects due to differences in scores on the pre-test needed to be applied. No apparent systematic difference between the groups existed. Age, sex, relevant previous experience and ability level factors appeared comparable for the two groups.

A sample of 226 second year science and non-science Diploma in Teaching students was used for the purpose of attitude scale construction, to provide data for item analysis.

The 17 subjects in the experimental group and the 15 subjects in the control group represented the total number of students enrolled in the first year physics at N.C.A.E. who intended to become secondary science teachers.

For six months the experimental and control groups attended Physics I lectures and laboratory sessions which were essentially the same for each group. The lecturer, content and approach were the same.

The pre-test presentation of the attitude scales was then conducted for both groups by their education lecturer, in the hope that tendency to produce socially desirable results would be reduced.

One week after the pre-test, the experimental group was introduced to methods of writing simple calculator programmes. They also discussed criteria which could be applied to aid them in identifying situations where writing such programmes in physics laboratory courses could be advantageous. The experimental group then completed the five-week programmable calculator experimental physics unit, while the control group did a five-week laboratory course which involved experiments which occurred in the calculator unit. These had been reorganised to avoid the necessity of performing arduous repetitive calculation. Asking the control group to do the same amount of calculation as the experimental group, without a programmable calculator, could produce a misleading difference in post-test attitudes due to a large drop in control group scores.

The same physics lecturer conducted the theoretical and laboratory physics course for all 32 subjects during the whole academic year, including the experimental phase. Great care was taken to ensure that, as far as possible, the only difference in experiences provided for the two groups consisted of the application of calculator programming in laboratory experience provided for the experimental group.

One week after conclusion of the five-week laboratory unit, when experiments had been written up, submitted, marked and returned, the experimental and control groups completed the post-test presentation of the attitude scales. This presentation also was conducted by the lecturer in education, as part of his normal tutorial session.

The instrument. The instrument used to detect attitude change consisted of three Likert-type scales, each of twenty items, ten of a positive nature and a similar ten of a negative nature.

The response required for each item was a tick against one of the following categories:

strongly agree,
agree,
neither agree nor disagree,
disagree,
strongly disagree.

For the positive items, the scores assigned to a response were 1, 2, 3, 4 and 5, with 'strongly agree' gaining the score of 5. For negative items, the order of the scores was reversed. Thus for these items, 'strongly disagree' attracted a score of 5.

The following items represent a sample from each of the three scales:

1. interest in conducting physics experiments;

   I would enjoy devising and conducting an experiment to measure the value of acceleration due to gravity, using an electronically operated stop-watch and an electromagnet.

2. interest in the study of physics in general;

   I would probably enjoy listening to a discussion between people interested in the basic laws and assumptions of physics.

3. confidence in own ability to master the use of complex equipment;

   Compared to learning time taken by the average first year tertiary science student, I would probably take a relatively short time to learn how to operate an electron microscope.

The proposed items were presented to some members of N.C.A.E. Science Department academic staff and some changes were made as a result of their suggestions.

During the test construction stage, the item analysis, based upon responses of the 226 second year students to the proposed items was conducted by a computer programme called Veldman Testat Test Instrument Analysis (modified by Dr M.N. Maddock, University of Newcastle), using The University of Newcastle's ICL 1940A computer.

The printout provided the following information:

1. the total score for each subject on each scale;
2. the point-biserial correlation coefficient for each item with respect to its particular subscale;

3. alpha coefficient values for each scale.

The values obtained for the point-biserial correlations ranged from 0.37 to 0.73, and as values of 0.25 are often accepted, these values were regarded as satisfactory (Nunnally, 1967, p. 263). Alpha is a measure of the reliability of the items in question. It results from an application of product-moment correlation to coefficient r to the determination of the extent to which the sample of items measures a unitary attribute.

TABLE 1

Alpha values obtained

Presentation	Scale 1	Scale 2	Scale 3	Total Scale
Preliminary	0.91	0.90	0.90	0.95
Pre-test	0.90	0.88	0.89	0.95
Post-test	0.92	0.91	0.83	0.95

The preliminary results were satisfactory, as reliability of around 0.90 for each scale is well above the alpha value of 0.80, which is often regarded as acceptable in the case of tests of this nature (Nunnally, 1967, p. 265). Estimates of reliability were calculated in a similar fashion from scores obtained by the 32 experimental and control group subjects in the pre-test and post-test presentations of the final scales. The alpha values are summarized in Table 1.

For the pre-test it was found that point-biserial correlation values were fairly evenly distributed between 0.3 and 0.8 with only two of the sixty items below this range, at 0.2.

For the post-test the point-biserial correlation values were fairly evenly distributed between 0.3 and 0.8 with a different two items falling below this range at 0.2.

The post-test results reveal that reliability for the scales is acceptable. The establishment of validity of the scales rests fairly heavily upon the opinion of science educators and scientists who were asked to comment upon the items.

The use of judges, who are experienced in research in the area of science education and who have examined affective outcomes in science teaching situations, was an attempt to establish some degree of content validity in the items selected.

Evidence supporting construct validity of the scale is provided by the observation that the experimental treatment produced theoretically predicted changes in attitude scores.

The unit of physics experiments involving use of the programmable calculator. The unit was not designed only with the specific purpose of producing attitude change. It was hoped that the students would gain a useful skill and would begin to see that to be freed from repetitive calculation in experimental work is not the only gain. The power to calculate easily and quickly enables the student to obtain more information about the relationship between variables under study, by looking at the behaviour of the variables at small intervals over a wide range of values.

For each experiment the student was given the aim and a very brief description of the method to be used to obtain observed values. Methods of theoretically predicting values were dealt with in theory lectures. In each experiment, the student was required to test the accuracy of predictions made, by comparing theoretical values with observed values.

Experiment 1 required the student to compare observed velocities of two pendulum balls after collision, with velocity values predicted using the equations of conservation of momentum and coefficient of restitution.

Experiment 2 required the student to determine moment of inertia (*I*) of a wheel, by applying Newton's Second Law to a situation where a falling mass caused the wheel to rotate. The student then compared *I* values with *I* determined from the geometrical properties of the wheel.

Experiment 3 required the student to determine the *I* of a bar and two movable masses on the bar, by the method described in experiment 2. Values of *I* were calculated for ten different positions of the masses along the bar. The shape of the graph of *I* versus radius was compared to the shape predicted by the equation

$$I = \sum_{i=1}^{N} m_i r_i^2$$

Experiment 4 required the student to determine the acceleration of mass 1 along an inclined plane for ten values of connected mass 2, which hung vertically over a pulley at the top edge of the inclined plane. These values were compared with values predicted by Newton's Second Law.

Experiment 5 required the student to determine the *I* values of hoops, spheres and disks by rolling them down a slope. These *I* values were compared with *I* values obtained from the geometrical properties of the objects.

All experiments required the student to write a calculator programme to obtain a number of values of either the predicted or the observed quantities.

After the experiment unit was completed by the experimental group, each member was able to write a simple calculator programme successfully, under examination conditions.

Analysis of data

There appears to be a division of opinion expressed in the literature concerning the advisability of assuming that scales such as those devised in the present study are interval scales. Seigel (1956, p. 31) points out that parmetric techniques for analysis of data should not be used unless the scores under analysis result from measurement in the strength of at least an interval scale. However, other sources of opinion (Labovitz, 1974, pp. 399-400; Popham, 1967, p. 273) suggest that minor divergences of the properties of such a scale from those of an interval scale do not invalidate the application of parametric techniques in analysis of scale scores. Observations of the action of adverbs as multipliers by Cliff (1959) suggest that divergences in the present study are relatively minor.

For the purposes of this study, the scale was assumed to have interval scale properties, and parametric techniques for data analysis, rather than the less powerful and less flexible equivalent nonparametric techniques, were used.

MacKay (1970) and Gardner (1972) report having used parametric tests of significance where the data consist of scores obtained from Likert-type scales.

Regression coefficients indicated that it would be invalid to use analysis of covariance to test for significance of difference between means of experimental and control groups' post-test attitude scores (Winer, 1962).

To test the significance of difference between means on the post-test, scores for each group were separated into those of individuals who scored above the grand mean on the pre-test and those who scored below it. Thus, when a two way analysis of variance was conducted using the post-test scores, it was possible to estimate the extent to which group differences in post-test scores could be explained in terms of initial attitude scores.

Findings

For the four scales, it was found that subjects who scored well on the pre-test also tended to score well on the post-test ($p < .01$). The post-test scores of the experimental group on *interest in experimental physics* were significantly higher than those of the control group ($p < .01$).

No significant effect of the treatment was found for the total attitude scale or for the scales of *interest in physics in general* and *confidence in ability to master the use of complex equipment.*

The means obtained on the three scales, and on the total test scores obtained by summing the scores on the three scales, are shown in Table 2.

TABLE 2

Group means for post-test

Scale	1 Interest in physics experiments		2 Interest in physics in general	
Group	Experimental	Control	Experimental	Control
Above mean on pre-test	76.45	61.33	73.45	65.00
Below mean on pre-test	58.33	54.00	54.83	56.00
Scale	3 Confidence in ability to master use of complex equipment		Total	
Group	Experimental	Control	Experimental	Control
Above mean on pre-test	71.69	72.50	219.83	191.67
Below mean on pre-test	59.50	61.09	172.00	174.33

Maximum score for each sub-scale is 100

TABLE 3

Summary of analyses of variance on post-test scores

Scale 1: Interest in experimental physics

Source of variation	Sum Sqs	DF	Mean Sq	F Ratio
Factor A (Initial attitude score)	1210.292	1	1210.292	19.438**
Factor B (Treatment)	706.971	1	706.971	11.345**
Interaction AB	217.385	1	217.386	3.491
Within Cell	1343.394	28	62.264	

Scale 2: Interest in physics in general

Source of variation	Sum Sqs	DF	Mean Sq	F Ratio
Factor A (Initial attitude score)	1452.005	1	1452.005	17.348**
Factor B (Treatment)	101.085	1	101.085	1.208
Interaction AB	176.174	1	176.174	2.105
Within Cell	2343.561	28	83.699	

Scale 3: Confidence in ability to master use of complex equipment

Source of variation	Sum Sqs	DF	Mean Sq	F Ratio
Factor A (Initial attitude score)	834.081	1	834.081	25.561**
Factor B (Treatment)	8.615	1	8.615	0.264
Interaction AB	0.919	1	0.919	0.028
Within Cell	913.671	28	32.631	

** ≡ significant F at .01 level

There was no evidence of significant interaction between the treatment and the initial attitude score on the three sub-scales, but significant interaction was indicated ($p < .05$). for the total attitude scale.

It should be noted that at the 0.1 level the hypothesis that the treatment would produce higher scores on the total scale post-test is supported. This observation suggests that a further study using larger numbers of subjects may succeed in supporting this hypothesis at an acceptable level of significance.

TABLE 4

Analysis of variance on total post-test scores
(Sixty items, twenty from each scale)

Source of variation	Sum Sqs	DF	Mean Sq	F Ratio
Factor A (Initial attitude score)	7568.366	1	7568.366	23.173**
Factor B (Treatment)	1189.356	1	1189.356	3.642
Interaction AB	1657.871	1	1657.871	5.076*
Within Cell	9145.000	28	326.607	

** significant F at .01
* significant F at .05

Cohen (1965, p. 99) suggests that whenever a test of significance of difference between group means is reported, a suitable correlation coefficient should also be calculated, to serve as a guide to the magnitude of the effect. If the correlation value is small, it will tend to preclude the usual misinterpreation of significance.

Cohen also indicates that a correlation value can be computed from F ratio values using the following relationship:

$$\epsilon = \sqrt{\frac{df_b(F-1)}{df_bF + df_w}}$$

The epsilon values obtained are summarized in Table 5.

TABLE 5

ϵ values for effects yielding significant F values

Scale	Factor	ϵ	% of variance accounted for
Interest in conducting physics experiments	Initial attitude score	0.62	38%
	Treatment	0.51	26%
Interest in physics in general	Initial attitude score	0.60	36%
Confidence in own ability to master use of complex equipment	Initial attitude score	0.68	46%
Total attitude scale	Initial attitude score	0.66	44%
	Treatment	0.29	8%
	Interaction	0.35	12%

The most interesting information to be gained from this table is the fact that experience of the programmable calculator physics laboratory unit accounted for a significant 26% of the variance obtained in 'interest in conducting physics experiments'.

Discussion and conclusions

Because pre-test mean scores were not referred to specifically in the two-way analysis of variance, it will be useful to describe the behaviours of group means. The means of each group taken alone were remarkably stable when pre-test and post-test scores are compared, for all scales except interest in experimental physics. This was also true when the pre-test and post-test means, calculated from the total of experimental and control group scores, are compared. These are summarized in Table 6.

TABLE 6

Group mean scores

Scale	Scale 1 Interest in Experimental Physics			Scale 2 Interest in Physics in general		
Group	Experimental	Control	Experimental plus Control	Experimental	Control	Experimental plus Control
Pre-test	71	64	68	68	63	65
Post-test	70	56	63	67	60	64
Scale	Scale 3 Confidence in ability to master use of complex equipment			Total		
Group	Experimental	Control	Experimental plus Control	Experimental	Control	Experimental plus Control
Pre-test	70	62	66	209	190	200
Post-test	69	64	67	206	181	194

Inspection of the means reveals that the significance of the treatment effect, found for scale 1 by the analysis of variance, stems from a reduction in mean score of the control group.

It appears that while most of the attitudes to physics being studied here tend to remain stable, the level of *interest in experimental physics*, is reduced by exposure to the normal physics course. The programmable calculator laboratory unit seems to have had the effect of keeping the level of interest in experimental physics from dropping below its initial value.

Inspection of the F ratios for interaction effects indicates that on the total scale only, subjects with high initial attitude scores tend to increase attitude scores more, as a result of the five week experience with the calculator laboratory unit, than do subjects with low initial attitude scores.

If one could generalise with safety from the results of this study, the following conclusions could be drawn. When subjects from the population under study complete the calculator laboratory unit described here:

1. the level of interest in experimental physics of the group is not reduced as much as it may be by experience of a conventional laboratory course;
2. there is little apparent effect upon professed interest in physics in general and upon professed level of confidence in ability to master the use of complex equipment;
3. greatest gains in scores on the net attitude scale presented here may be made by those with a high initial score on the 'total' scale.

However, this study would need to be conducted using many student groups and lecturers before such generalisations could be made with any confidence. Because the attitude scales behaved quite well in the present study, application of some of these may be of use in further studies.

The present study should be regarded as a pilot study. The student numbers available were small. Inclusion of students from other colleges would increase the number of subjects and make possible the use of a more sophisticated experimental design. However, it would make control of variables which could affect attitudes to physics very difficult.

Possibly this problem could be overcome by applying the present research to a large number of schools, with random assignment of teachers and schools to experimental and control groups.

The form of the experiments and attitude scales would need to be modified to suit a population of school students.

The results of the pilot study suggest that conducting a further study as outlined above is justifiable.

References

BLIGH, P.A. "The use of computers in teaching statistical physics at Nuffield, A level." *Physics Education*, **9**: 403-408, 1974.

BONGARZONE, E.J. "Citizen's science teaching, the man made world." *The Science Teacher*, **37**(*5*), 1970.

CLIFF, N. "Adverbs as multipliers." *Psychological Review*, **66**(*1*), 27-44, 1959.

COHEN, J. "Some statistical issues in psychological research", in Wolman, B.B. (Ed.) *Handbook of Clinical Psychology*. McGraw-Hill, New York, 1965.

CRAIG, J.C. "Simulating air quality investigations with the programmable calculator." *The Science Teacher*, **41**(*4*), 1974

DEAN, P.G. "A view of computing, mathematics, and science in British education. *School, Science and Mathematics.* **75**(*1*): 21-29, 1975.

ELMER, R.P. "Computers, how and why use them in high school." *The Science Teacher,* **36**(*8*), 1969.

GARDNER, P.L. *Attitude to Physics: A Study of Personal and Environmental Influences on the Attitudes of High School Physics Students.* Ph.D. Monash University, 1972.

LABOVITZ, S. "The assignment of numbers to rank order categories", in Maranell, Gary M. (Ed.), (Ed.), *Scaling: A sourcebook for behavioural scientists.* Aldine, Chicago, 399-400, 1974.

MACKAY, L.D. "Changes in Victorian physics students during two years of physics study." *The Australian Physicist,* 103-109, 1970.

MALPAS, A.J. "Computer simulation of modern analytical procedures in sixth form chemistry." *School Science Review,* **55**: 193, 1974.

NUNNALLY, J.C. *Psychometric Theory.* McGraw-Hill, New York, 1967.

POPHAM, W.J. *Educational statistics, use and interpretation.* Harper & Row, New York, 1967.

SANDERY, P. "Simulation: Use of the computer in secondary science." *Australian Science Teachers' Journal,* **20**(*1*): 111-118, 1974.

SEIGEL, S. *Nonparametric Statistics for the Behavioural Sciences.* New York, McGraw-Hill, 1956.

SHIRER, D.L. "Computers in physics teaching." *American Journal of Physics,* **41**: 1209, 1973.

SHOWALTER, V.M. "Conducting science investigations and computer simulated experiments." *The Science Teacher,* **37**(*7*), 1970.

SLAGLE, R.D. "Computer assisted learning." *The Science Teacher,* **56**(*1*), 1969.

SUMMERLIN, L. "Student attitude toward computer assisted instruction in chemistry." *The Science Teacher,* **38**(*34*), 1971.

WINER, B.J. *Statistical Principles in Experimental Design.* McGraw-Hill, New York, 1962.

THE DEVELOPMENT OF SCIENCE CONCEPTS IN PRIMARY CHILDREN BY DISCOVERY STRATEGIES

I.A. Napper

Abstract

A year three/four class of thirty primary school children was selected and then exposed to a series of twenty discovery lessons on electricity, discovery learning being:

> The learning of scientific principles or concepts which occurs as a generalisation of experiences by the learner in the absence of direct telling by the teacher.
> (Carin and Sund, 1975)

The performance of these children was evaluated, both before and after the discovery lessons, on the basis of their ability to solve problems requiring the application of one or more of the thirteen concepts covered.

On comparing the performance of the "discovery" class on pre-test items with the performance of children from years three and four, as well as five to seven in other Perth suburban schools on subsets of these items, it was found that the "discovery" group was no better and no worse than other primary classes. A team of ten graders (examiners) was used for rating purposes.

The Rasch Model was the statistical model used and enabled comparison to be made between the "discovery" group and all other class groups.

Purpose

As a starting point, the following hypothesis was chosen:

> Children can develop science concepts through involvement in discovery activities and apply these concepts to solve problems they have not met before. It is not necessary for children to verbalise a discovered concept for the child to be able to use it. This has been called unverbalised awareness.

In detail the project should show that:

(a) children can state the discovered concepts in their own words if asked;
(b) given a problem requiring the application of a given concept in order to reach a solution, the children will apply the concept;
(c) given a situation contradictory to the concept, the children will be able to explain that it is wrong.

Discovery

Carin and Sund (1975), in *Teaching Science Through Discovery*, define discovery learning as:

> The learning of scientific principles or concepts which occurs as a generalisation of experiences by the learner in the absence of direct telling by the teacher.

Bruner (1961), in *The Act of Discovery*, says:

> I do not restrict discovery to the act of finding out something that before was unknown to mankind, but rather include all forms of obtaining knowledge for oneself by the use of one's own mind . . . .

Concepts

As the strategy used was guided discovery (Carin and Sund, 1975), thirteen concepts in electricity were chosen. Concepts covered were:

1. metals are conductors;
2. non-metals (except carbon) are non conductors;
3. an electric current requires a complete circuit for a current to flow;
4. when a conductor is moved in a magnetic field, a current is produced;
5. two unlike metals, immersed in a solution that acts chemically on one more rapidly than on the other, will produce an electric current;
6. an electric current passing through a conductor produces a magnetic field around the conductor;
7. the strength of the magnetic field around a conductor is proportional to the current;
8. in an electromagnet, the strength can be increased by–
   (a) increasing the number of turns around the core;
   (b) increasing the amount of current;
9. in a series circuit, all the current travels through all parts of the circuit in turn;
10. in a parallel circuit, the current travels through alternate pathways;
11. the components of a circuit can be represented by sumbols;
12. when a conductor resists the flow of electricity, heat is generated;
13. an electric motor can be made using a magnet and a coil.

Testing programme

It was proposed to pretest the concepts to be discovered at the beginning of each week by "journal" assignment and then post-test by classroom assignment at the end of the week, after two discovery lessons had occurred. The "journal" assignment would be done at home and children would receive a token reward for just returning this type of assignment, complete or incomplete.

The schedule of assignments was as set out below.

Pre-test		*Post-test*
Journal Assignment	Week	Class Assignment
Problem 1 on Concept 1	1	
Problem 2 on Concept 2	2 Concept 1 covered	Problem 1a on Concept 1
Problem 3 on Concept 3	3 Concept 2 covered	Problem 2a on Concept 2

The format of all assignments would revolve around an hypothetical John and Mary, one of whom poses a problem situation and the other offers a solution.

The children being tested must –

(a) judge whether the solution offered is right or wrong;
(b) give reasons for their answer.

Appendix A shows an example of a completed "journal" assignment and an example of a completed class assignment.

Let it be stressed that the whole project was designed to show that if primary science is taught in this manner, these sorts of results can be obtained, **NOT** that a particular teaching strategy is better than another given strategy.

Although other schools were involved, it was only to show that the discovery group were no better or worse than other children in Western Australian primary schools before they experienced the discovery activities.

Method

The Class. A year 3/4 class at East Claremont Practise School was chosen. The class consisted of 30 children:

Year 3 – 7 children (3 boys, 4 girls),
Year 4 – 23 children (15 boys, 8 girls).

The class teacher regularly ran science lessons (one lesson of approximately 30 minutes per week) and the children were used to working in groups. Science lessons tended to be largely teacher directed but the class did carry out experiments in small groups.

The Assignments. As it was hoped to show that the strategy would bring about a difference in performance on pre- and post-test problems, as mentioned already two types of assignments were planned –

"journal" assignments;
class assignments.

The "journal" assignments were given to children to be done at home, but two problems rapidly arose which necessitated an alteration in the pre-test:

(a) not all children returned the assignments;
(b) children involved their parents in solving the problem posed by the journal assignments (see the example of a "journal" assignment, Appendix A, No. 1).

While this was desirable from a teaching point of view, it did not provide accurate data about the children before experiencing the discovery lessons. Many children when confronted with a problem in the "journal" assignment went either to an authority, either parent, or assembled the materials at home and solved the problem.

In order to have accurate information about the class before the discovery activities, a new pre-test (a class assignment) was attempted in class at the beginning of each week. However, the "journal" assignments continued week by week for the whole ten weeks of the experiment. Thus each week each child was given a "journal" assignment (a pre-test), a classroom pre-test and post-test. The completed assignments were collected week by week, the children receiving no feedback as to the accuracy of their assignments. If they could not do a particular assignment they just wrote "I can't do this".

Many children displayed guilt feelings about being unable to satisfactorily complete the assignments even though they had never been taught the material being tested.

The Groups. The significance of grouping was not apparent until at week six the class teacher asked for feedback from the children on the discovery lessons. The class groups had been teacher structured and resulted in –

4 groups of 4 children
2 groups of 5 children
1 group of 3 children.

All groups contained both boys and girls and each had a group leader designated by the class teacher.

The two principal factors were -

(a) some group interaction was affecting attitudes to science (see Appendix B, statements 1 to 7);

(b) even at a year 4 level (9 year olds) some girls were expressing negative attitudes to science (see Appendix B, statements 8 and 9).

Immediately the groups were restructured, with the children choosing with whom they would like to work. There were still seven groups but now the composition was –

2 all male groups of 4
2 all female groups of 4
2 mixed groups of 5
1 mixed group of 4.

The contrast in the lessons was marked – no more complaints by children of their group partners preventing them from trying the discovery activities. The most obvious advantage of a group structure is the incidental learning that occurs as members interact.

Examples of comments made after the restructuring of groups are shown in Appendix B, statements 10 to 14.

The Lessons. The pattern chosen for the lessons was that advocated by Carin and Sund (1975). The particular strategy was *guided discovery* (Carin and Sund, 1975), in which the teacher identifies the concepts the children should discover and then structures a series of discovery activities. It should be stressed that:

(a) no attempt was made, at any time, to verbalise the concepts;

(b) in all situations it was the experience with the materials which gave the children the concepts – the children developed a state of unverbalised awareness so that, as the results showed, they were capable of solving problems with the discovered concepts without knowing that they had established a given concept and without any formal instruction;

(c) no form of recording, whatever, was used for the whole of the discovery lessons, recall depending on what was *done* practically in class.

A sample of lesson format is given in Appendix C.

Two types of lessons were used:

1. *Introductory* – in which concepts were discovered for the first time;
2. *Reinforcement* – in which the concepts discovered were reinforced, these tending to be lessons in which concepts were applied.

The Equipment. While all the equipment used in the study was supplied by Claremont Teachers College, it is of the type readily available to teachers, with the possible exception of galvanometers. The basic equipment was –

1.5 V PMG cells
PVC covered leads with alligator clips
1.2 V torch globes
Metal sockets for globes
Tapping key.

Children's Developing Facility. As the series of lessons progressed the children developed considerable skill not only in connecting circuits but also in tracing and identifying faults in their circuits. Should a group reach frustration point, it then became necessary to step in and by questioning, redirect their thinking and endeavours.

Demonstration versus Discovery. In the lesson on conductors and non-conductors it was necessary to show carbon was a conductor by demonstration. In solving the problems involving the concept that carbon is a conductor, it became increasingly obvious that children were uncertain about the conductivity of carbon. This emphasized the decreased effectiveness of demonstration when compared with first hand, multi-sensory experience.

Spin-Off Mention has been made already of parental involvement in reference to "journal" assignments, however other "spin-off" occurred.

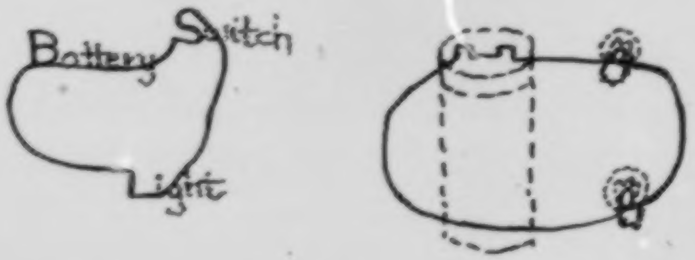
Perhaps the most outstanding was that a number of children, who, when supplied with the equipment, in their recess and lunch time completely wired a doll's house which was in the classroom. The outstanding feature was the approximation to normal domestic circuitry and their involvement to the extent of sacrificing normal play time.

A further "spin off" was the frequent appearance of electrical equipment from home in the form of car ammeters, slot car motors, leads and wire in profusion, switches, cells, to mention but a few. It was common to see small groups investigating and playing with this gear.

Such free discovery eventually led to further reading to help solve the problems raised by the equipment.

Circuit Diagrams. The class learned to use simple circuit diagrams with facility. It was felt that the use of a circuit symbol was no more difficult to conceptualise than the use of a mathematical symbol.

The class was introduced to circuit diagrams by each group devising a circuit and then representing their circuit in code. This coded circuit they then passed to another group to make up the coded circuit. Groups quickly discovered that a unique coding communicates very little. Figure 1 shows two examples of coded circuit diagrams and their interpretation.



——— Unbroken lines are childrens' circuit diagrams.

– – – Broken lines provide interpretation of childrens' diagrams.

FIGURE 1. Circuit diagrams

The class rapidly appreciated the need for a convention on coding and readily used the conventional symbols.

Child Reaction. No one could teach by discovery and not be moved by the excited response of children to a discovery made. The desire to show what they had found was completely uninhibited and often resulted in loud cries of excitement to obtain attention for the discovery.

There is little doubt that this strategy has an intrinsic reward as suggested by Bruner (1961) in *The Act of Discovery*–

> learning that starts in response to rewards of parental or teacher approval or the avoidance of failure can too readily develop a pattern in which the child is seeking cues as to how to conform to what is expected of him. The child becomes self-motivated when he approaches learning by discovering something rather than 'learning about' it. Such a learner has the tendency to carry out his activities with the autonomy of self-reward, or more properly by reward that is discovery itself.

The Teacher's Role. The teacher (the author) determined the scope and sequence of the discovery programme, designed the discovery activities and then attempted to stimulate the children's thinking by asking questions and posing problems. This was done principally at group level when the class was involved in the discovery activities.

Another task was to provide clues when children were bogged down in discovery learning, to keep the process moving. According to Renner (1967):

> This can best be done by supplying clues and cues when children are 'stuck'.

This was done in the discovery lessons.

The Rasch model

George Rasch, a Danish mathematician, proposed a model for objective measurement of attainment (ability) (Rasch 1960). This model can be applied to dichotomously scored items and so may be used in the scoring of multiple choice objective questions and dichotomously scored short answer questions.

> The basis of the proposed model is the postulate that it is possible to speak of the encounter of a person with an item – an encounter which is either successful or unsuccessful, i.e. right or wrong – in terms of just two factors, one specific to the person and one specific to the item; these two factors are *parameters* of the model and are taken to be constant for a given person or item. (Willmott and Fowles, 1974.)

Thus the person-specific parameter, whose value is the measure of the person's attainment or ability, is taken to be *constant for a given person regardless of the items that the person attempts* and the item – specific parameter, the item's difficulty, is taken to be *constant for a given item regardless of the persons attempting that item.* Since these values have been determined for the items, it does not matter, from the point of view of getting a subject's measure of ability, which subset of items (test) a person takes at any one time and it does not matter *who* takes the subset of items (test) in company with that person, providing the model holds and this can be checked.

The Rasch model is, by definition, of a probabilistic nature. If there are some items which do not fit the model then these items are rejected and only those that fit the model and to which the above properties can justifiably be ascribed are accepted.

Results

Other Schools. In order to compare the discovery class with other classes, five schools in the Perth metropolitcan area were chosen. All years from 3 to 7 were given a set of four assignments to complete (the four assignments were chosen at random from all the assignments used on the Claremont discovery group). No one school did the same set of assignments as any other school. The schools and years used for comparison are shown in Table 1.

TABLE 1

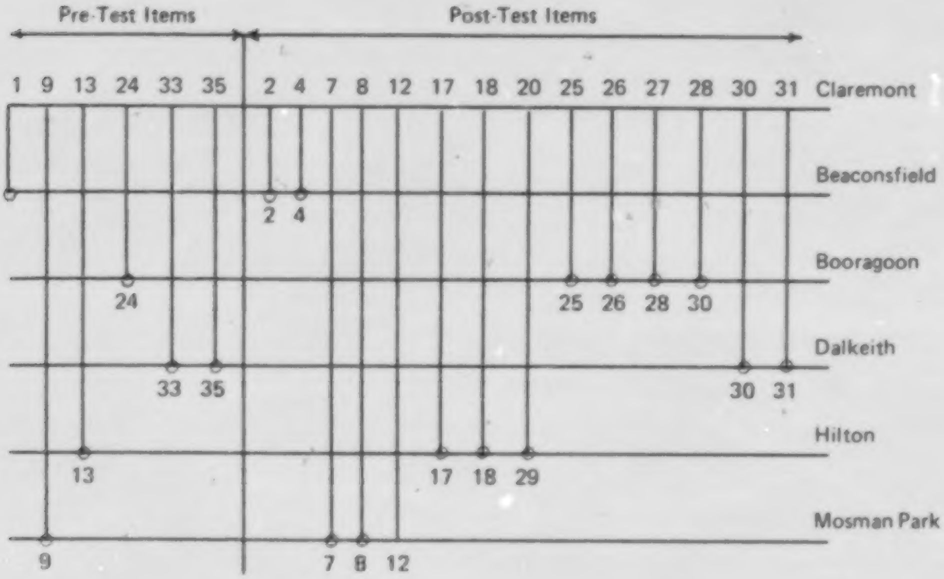
Schools and years used for comparison with Claremont year 3/4

Beaconsfield	Booragoon	Dalkeith	Hilton	Mosman Park
3	3/4	3	3	3/4
4	4/5	3/4	4	4
5	5/6	4	5	5
6	6	5	5/6	6
7	6/7	5/6	6/7	7
	7	6/7	7	
		7		

Note that the Rasch model still enables comparisons between schools (even though different items were used in different schools), provided there is a link. Here the link is provided by Claremont. This comparison with five other schools was an attempt to show that prior to the discovery activities, Claremont children were no better and no worse than children from other primary schools in Perth.

TABLE 2

Test item distribution


Pre-Test Items
Post-Test Items
1 9 13 24 33 35
2 4 7 8 12 17 18 20 25 26 27 28 30 31
Claremont
Beaconsfield
2 4
Booragoon
24
25 26 28 30
Dalkeith
33 35
30 31
Hilton
13
17 18 29
Mosman Park
9
7 8 12

The Graders. In order to obtain objectivity in scoring items, ten test graders were recruited from the student body of Claremont College of Advanced Education and briefed on the method of grading to be used on all papers.

At the same time, the items completed on both pre- and post-tests by the discovery group (Claremont) were intermingled with the papers from the five other schools. All identifiable marks were removed from the papers, which were then coded. Thus the graders had no knowledge of the origin of any paper they were grading. All items (whether used for analysis or not) were scored –

2 – right
1 – half right
0 – wrong.

Once the scoring was completed, the data obtained was processed by the ISGPAR programme at the Regional Computer Centre, University of W.A.

Grader Reliability. Grader marking was checked for conformity to the model, the graders being treated just like items. All ten graders conformed to the model.

Item Difficulty. One of the features of the model is that it gives an estimate of the item difficulty independent of the subjects who take those items, provided that the items fit the model. Altogether twenty items out of a possible thirty items were chosen and for each item an estimate of relative difficulty can be obtained. The values obtained are summarized in Table 3.

TABLE 3

Values for item difficulty

Type	Item No.	Difficulty
Pre-Test	1	1.2217
	9	1.6754
	13	0.7068
	24	0.5957
	33	0.0811
	35	-0.3146
Post-Test	2	1.6356
	4	1.2094
	7	-0.4136
	8	0.0773
	12	0.1327
	17	-0.5840
	18	-0.2941
	20	0.3225
	25	0.2234
	26	0.7085
	27	0.4136
	28	0.0773
	30	-0.7809
	31	1.2171

Note: Type category only with reference to Claremont.

Comparison of Discovery Group with Other Schools. As the project was trying to show that Claremont children were no different to other children on a given set of items before experiencing the discovery activities, then a comparison of the mean ability for all other classes compared with the mean ability of the Claremont class on the pre-tests should show this (see Table 4 and Figure 2).

The Scheffé method of multiple comparisons was applied and there was found to be no significant difference between the classes. Note that the discovery group was a year 3/4 group and it was compared with classes from years 3 to 7 in other Perth primary schools.

TABLE 4

Comparison of mean ability by school and year

School number						
1	2	3	5	6	4 (Pre)	4 (Post)
15(3) 41(4) 40(5) 58(6) 63(7)	45(3/4) 60(4/5) 46(5/6) 59(6) 56(6/7) 64(7)	40(3) 56(3/4) 42(4) 54(5) 63(5/6) 60(6/7) 59(7)	25(3) 43(4) 46(5) 51(5/6) 46(6/7) 43(7)	39(3/4) 46(4) 44(5) 56(6) 53(7)	57(3/4)	71(3/4)

School No.
1. – Beaconsfield 2. – Booragoon 3. – Dalkeith 5. – Hilton 6. – Mosman Park 4. Claremont
(Figures in brackets denote year)

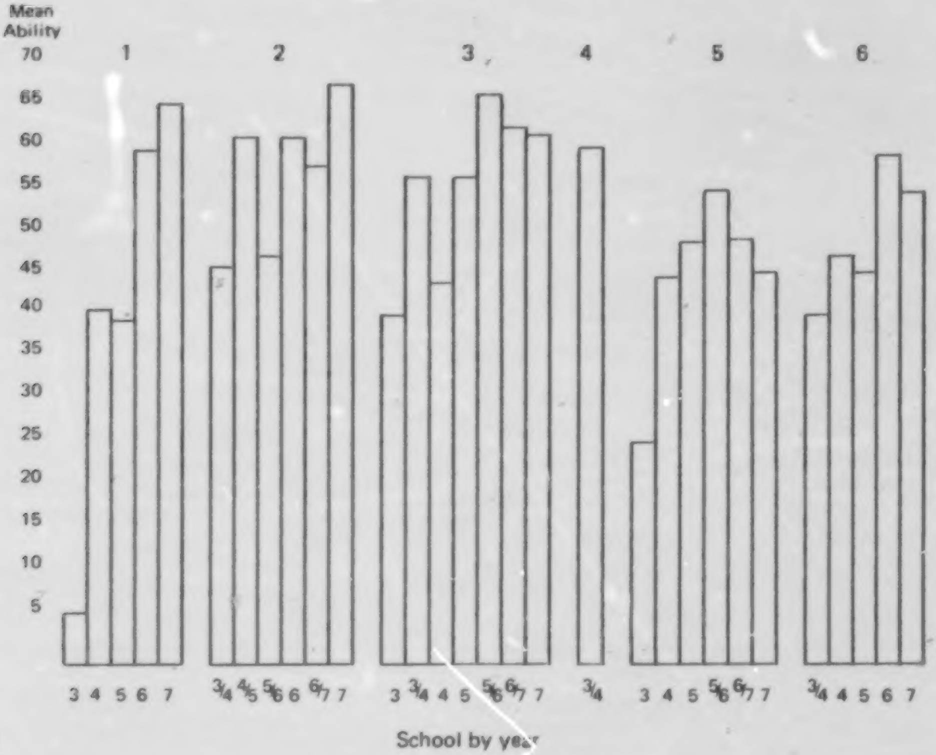


FIGURE 2. Comparison of mean abilities by school and year

Comparison of Pre- and Post-Test Ability Parameters for Claremont Children. The model provides an estimate of ability (attainment) for a given subject on a given set of items. Table 5 shows the comparison of ability on pre- and post-tests for the discovery group (Claremont). The figures in the table have all been multiplied by a constant to give a whole number between 0 and 100.

TABLE 5

Comparison of ability for pre- and post-test school no. 4 Claremont

Pupil	Ability	Pupil	Ability
301	71	301	81
302	45	302	60
303	45	303	68
304	61	304	74
305	68	305	66
306	65	306	72
307	59	307	67
408	46	408	69
409	56	409	68
410	55	410	65
411	51	411	59
412	62	412	78
413	70	413	79
414	67	414	85
415	63	415	74
416	59	416	83
417	65	417	86
418	50	418	66
419	64	419	74
420	63	420	77
421	69	421	63
422	56	422	69
423	38	423	69
424	60	424	59
425	57	425	77
426	55	426	69
427	55	427	63
428	40	428	62
429	33	429	75
430	72	430	76

A graphical representation more readily shows the shift in the children's ability (attainment) on the two sets of items (see Figure 3).

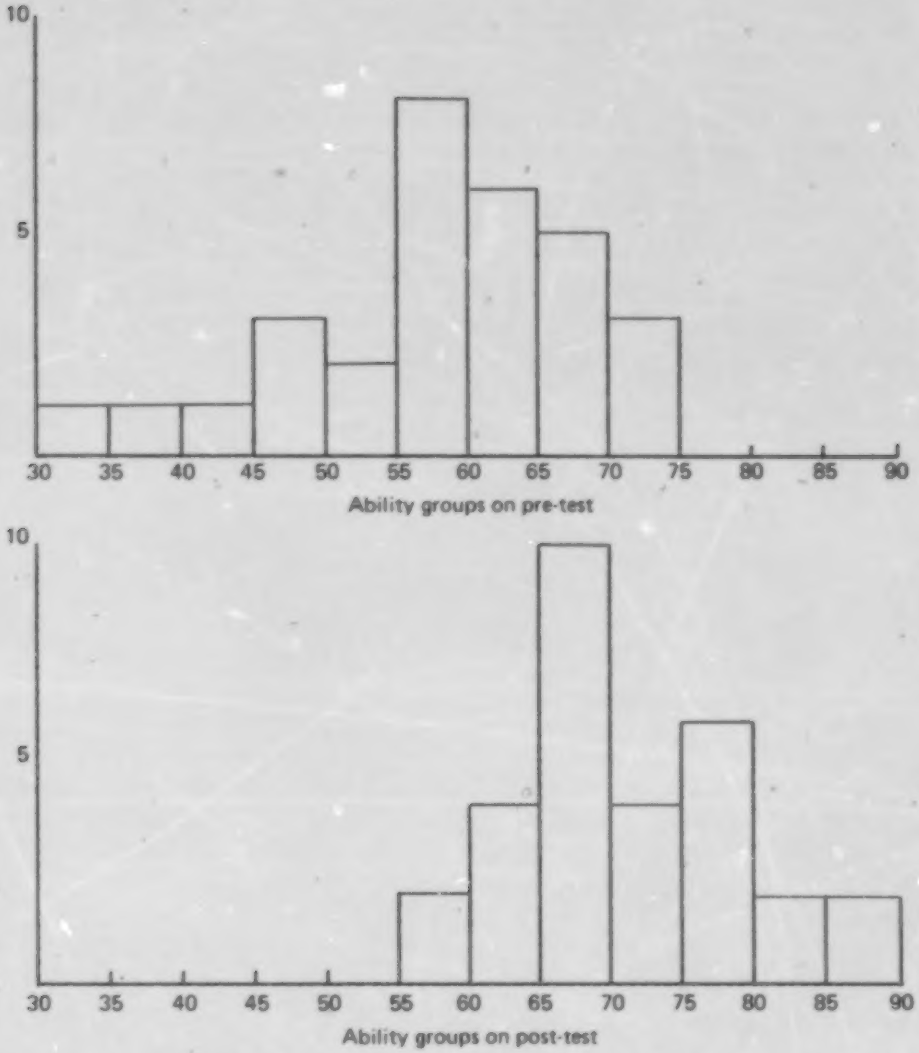


FIGURE 3. Comparisons of abilities on pre- and post-tests

The improvement was found to be significant at the .0005 level.

While the statistics show a marked difference in performance, they in no way show the excitement and interest manifested in the class, nor do they give the remotest indication of the positive feedback obtained when working with these children and using this strategy.

References

BRUNER, J.S. "The act of discovery." *Harvard Educational Review*, **31**(*1*), 1961.

CARIN, A.A. & SUND, R.B. *Teaching Science through Discovery*, 3rd Ed., Charles E. Merrill Columbus, Ohio, 1975.

RASCH, G. *Probabilistic Models for some Intelligence and Attainment Tests*, Danish Institute of Educational Research, Copenhagen, 1960.

RENNER, J.W. "A case for inquiry." *Science and Children*, March 1967.

WILMOTT, A.S. & FOWLES, D.E. *The Objective Interpretation of Test Performance, the Rasch Model Applied*, NFER Publishing Co., Windsor, Berks., 1974.

Acknowledgements

Acknowledgement is made of the help of Dr. Rosemary Hake of the University of Chicago in the design of the assignments and of Dr. David Andrich of the University of Western Australia who helped in the experimental design and application of the Rasch Model.

APPENDIX

A. Examples of completed assignments

1. Journal assignment

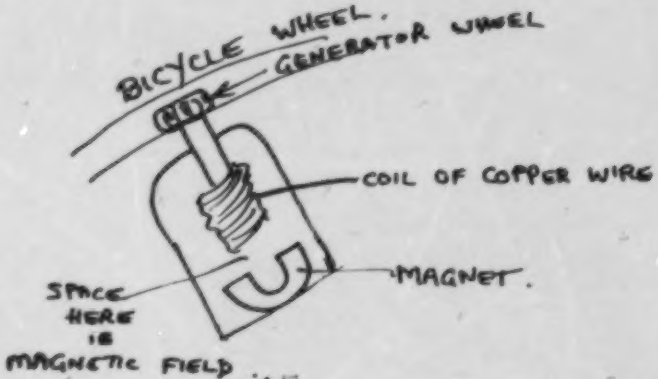
John has a bicycle with its own lights. The bicycle has a generator to make the lights go on. John opens up the generator and finds it contains a coil of wire and a magnet.

Mary asks; "How does it make electricity John?"

John answers; "Maybe the magnet pulls the electricity from the wire like it picks up nails".

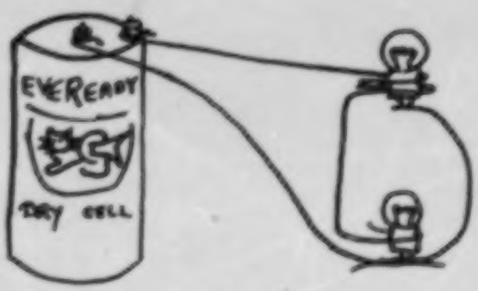
Is John right or wrong? If he is right, why is he right? If he is wrong, why is he wrong?

John is wrong because ~~my Mummy is smart & she says or~~ what actually happens, is that the wheel turns the coil of copper wire (as the bicycle wheel goes around with the small generator wheel against it) – and at a great speed – the electricity being generated by the wire because it is in the "magnetic field" of the magnet in the generator.


BICYCLE WHEEL.
GENERATOR WHEEL
COIL OF COPPER WIRE
MAGNET.
SPACE HERE IS MAGNETIC FIELD

2. Class assignment

Mary has a big battery, four pieces of wire and two torch globes. Mary uses the battery, wire and torch globes like this.



John says only one light will go on.

Is John right or wrong? If he is right why is he right? If he is wrong, why is he wrong?

Yes John is right.
Only one light will work.
Because the connections are
right for the top torch
globe only.

B. Statements from children on discovery lessons, in childrens' own words.

Examples of comments showing interaction in a given group.

1. I dont like it because Lincoln acts too much of a boss. I would like Luke because he is nicer ! like the sheets. Because they are interesting.

2. I don't like science becaus Linc won't give us a turn at putting it together. Sometimes he let's me but not all the time.

3. I don't like it because Lincoln won't let us have a go.

4. I like science because it's on electricity and because I'm the group leader. I have a bad group. And I would like to leave the group.

Examples of comments showing other interactions.

5. I hate sicence because Andrew Scl does not let me set it up. I like it only a little bit, because he lets me sometimes when Andrew P were not here.

6. I don't like sciance course because he gives us the homework sheets and I hatc doing nothing because they dont test no do nothing.

7. I don't like it Because evrey one teses me and the doys don't let you have a go.

Examples of comments by 9 year-old girls indicating negative attitudes.

8. I don't like the science cause becaus its a man's subject difiult to work out without a boy, and I'm not the sort of girl.

9. I don't like science because I don't like man job and boys don't let you have a chance of dong it or have a go. and I don't like science sheets.

Examples of comments after restructuring of groups on the basis of children's choices.

10. I like Science because everyone is far The last 6 weeks I have liked it. I am pleased with my group. I like the activities.

11. Liggys group is better because we have a chance of having a go. I like science now because it is exciting. And Im pleased of it.

12. I like Sience now. In the last six weeks have been better. I like ~~in~~ my chosen group.

13. I like science because I hav two friends in th groop and there is good ecwipment an it is fun.

14. I like sciece because it is my best subject and I'm interested in it. I like my group and I like my group leader which is Stewart.

C. Sample of a lesson format used in the project

19 SEPTEMBER 1974

LESSON NO. 2 ON CONCEPTS 1, 2 AND 3

PROBLEM: HOW DO YOU MAKE A GLOBE LIGHT UP?

CONCEPTS: NO. 1 METALS ARE CONDUCTORS
NO. 2 NON-METALS (EXCEPT CARBON) ARE NON-CONDUCTORS
NO. 3 AN ELECTRIC CURRENT REQUIRES A COMPLETE CIRCUIT FOR THE CURRENT TO FLOW.

MATERIALS PER GROUP:

1	1.5 VOLT PMG CELL
2	PVC INSULATED LEADS UNSTRIPPED
2	½ M. LENGTHS OF ENAMELLED WIRE
1	1.2 VOLT TORCH BULB
1	BULK SOCKET
1	PAPER CLIP
3	DRAWING PINS
1	BLOCK OF WOOD 5 x 5 x 1.25 CM.

DISCUSSION:

WHAT DID YOU FIND OUT LAST LESSON? WHAT SORT OF THINGS ARE CONDUCTORS? WHAT SORT OF THINGS ARE NON-CONDUCTORS? OUTLINE PROBLEM, VIZ. TO GET THE BULB TO LIGHT USING FIRST THE PVC COVERED WIRE AND THEN THE ENAMELLED WIRE.

PUPIL DISCOVERY ACTIVITIES:

1. USING A CELL, 2 PVC COVERED LEADS, A 1.2 VOLT BULB AND SOCKET GET THE LIGHT TO WORK.
2. NOW USE THE OTHER (ENAMELLED) WIRE AND GET THE LIGHT TO WORK.
3. USING THE PIECE OF WOOD, DRAWING PINS AND PAPER CLIP, MAKE A SWITCH AND PUT IT INTO THE CIRCUIT.

DISCUSSION:

WHAT DID YOU HAVE TO DO IN EACH CASE TO GET THE LIGHT TO WORK? WHAT WAS ON EACH OF THE TWO TYPES OF WIRE?

NORMAL SCIENCE AND SCIENCE EDUCATION

J.E. Butler

Introduction

This paper has been written in the conviction that the present malaise in the physical sciences at the school level has its origins in the logical structure of normal or completed science. This structure, under contemporary philosophical analysis, is characterized by theories that are hypothetico-deductive systems, and deductive-nomological explanations.

The following argument is meant to show that the type of school science derived from normal science (the latter appearing in definitive texts) is inappropriate for mass secondary education. This does not imply agreement with those, for example Feyerabend (1970), who claim that this derivative scientific education is also inappropriate for the education of scientific scholars.

To claim that something is very wrong with school science curricula is hardly being original (Young, 1974; Bondi, 1975). Many changes have been effected in science curricula to meet this problem. But most of these changes are purely cosmetic; to quote Smolicz and Nunan (1975):

> More than a trivial restructuring of the content of science is required to correct this school emphasis; indeed we need to further consider Kuhn's suggestion of a re-imaging of science. Only a new set of educational directives from a new conceptual basis can counter the distortions inherent in School Science.

This paper argues that what is needed is a genuine Kuhnian revolution, in the full sense of this word as a paradigm shift. Regretfully, the present analysis only shows the inappropriateness of the present academic (derivative) science curricula for mass secondary education. This is, it only criticizes the present paradigm. The erection of a new conceptual basis and the subsequent derivation of a new set of educational objectives are tasks for the future.

In particular, this paper analyses the role of idealizations in scientific theories and explanations, and the role of problem-solving, in the traditional academic model of scientific education. The alternative model for mass secondary education cannot yet be made explicit. But the inappropriateness of the former model for the new task will become apparent if the analyses are seen in the context of the following assumption about mass secondary science education: that it be meaningful to all students, that it considers science along with its social nexus, and that it be existentially relevant.

Kuhnian analysis of science

The starting point for a derivative science curriculum is the specification of goals. These are assumed to be found in the analysis by Kuhn (1970) of the structure of the mature physical sciences.

Briefly, Kuhn sees science as being done by a collection of more or less self-contained micro-communities of scientists, each with their own paradigm. These communities engage in a succession of two different patterns of thought and action: namely, normal science and scientific revolutions.

According to Kuhn:

(a) normal science is monistic, with the group of scientists engaged in interacting with the natural world in terms of a single paradigm;

(b) scientific revolutions are pluralistic – the community is confused by a plethora of paradigms until a new dominant paradigm emerges and routs the others.

Normal science is large and well entrenched. Most scientists do normal science. That is to say, they subscribe to the dominant paradigm and solve puzzles inside of it. Mopping-up operations are, according to Kuhn, what engage most scientists throughout their careers.

The particular aspect that needs attention here is the type of problem or puzzle that the scientists choose. There is general agreement (Kuhn, 1962; Ashby, 1971) that these problems have two essential characteristics:

(a) that they are likely to be soluble and

(b) that their solution will be relevant to concepts in the current paradigm.

Under these criteria the puzzles in the natural world are divided into two groups, the tractable and relevant on the one hand and the intractable and irrelevant on the other. This division has at least one unfortunate side effect, the latter group of problems, because they are never tackled, come to be regarded as unimportant.

The central importance of the choice of which problems are to be called scientific problems and which are not, was highlighted by Bondi (1975) at the recent physics education conference in Scotland. Bondi states that:

> . . . the greatest challenge to the scientist is to pick out problems that are amenable to solution . . . So to take a mish mash of information, to pick out the part you can solve and to leave the rest is perhaps the most important contribution of the scientist to his subject . . . But how often do we teach that scientific genius lies in selecting the soluble.

Such a categorization of problems seems hardly appropriate for teaching to people who must live and survive in the real world!

Educating to normal science

The education of a scientist is to prepare him to do normal science. This clearly involves two objectives – the introduction of the person to the current paradigm and training the person in the puzzle solving tradition. For example, Ziman (1968) sees the job of the science teachers as primarily to make all plain and plausible, to encourage the student to entrust himself freely to the basic paradigms. Ziman considers the expression of doubts or the issuing of warnings at this stage will inhibit the confident use of the new technique and the new language.

Kuhn discusses at length the role of practice problem-solving, both with pencil and paper and with instruments in the laboratory, in the learning of the current theories.

Smolicz and Nunan (1975) describe the highly academic and community restricted education which is presently given in our schools as one essentially designed for the needs of normal science. And Smolicz (1974) in an earlier publication states that:

> it would be pointless to deny that this type of scientific education is highly prevalent, or that Kuhn's theory mirrors it very accurately.

The next two sections will now go on to analyse these two facets – introduction to the current paradigms and puzzle-solving tradition — in greater detail.

Scientific theories: Role of idealizations

For the purposes of this section the meaning of paradigm will be restricted to that of the simpler term of theory. The main function of scientific theories is to provide explanations of natural phenomena.

However, as shown in the previous section, the rule in science is not to attempt explanations of complex phenomena at all. Paradoxically enough, the conceptual conquest of reality starts by *idealizing* it. For example, Ziman (1968) states that:

> In Physics, when we find a complicated object that cannot be described in simple geometry or by a few equations, we knock it into smaller pieces, or we purify and recrystallize it, or we cool it down, or we heat it up, until it becomes amenable to mathematical analysis.

Which leads one to agree with Bunge (1973) who claims that physical theories are not portraits of reality, but brutal simplifications leading to ideal schemas, such as homogeneous fields and free particles. It is the nature and role of these idealizations that will be examined in the following two subsections.

Idealizations and predicates. These idealizations usually take the form of the extreme value of some variable; for example, ideal gas, black body or material point. They occur in conceptual systems and designate no actual entity. They arise in the following manner.

In scientific thought, as elsewhere, abstract concepts are formed by identifying different objects which are connected by a relation of a type of equality. This method is called abstraction of identity and many of the primitive scientific concepts could not be formed without it. Abstract concepts designated idealizations, involve on the one hand, abstraction of identity, and on the other, the establishment of a certain ordered series and a transition to a special, fictitious limiting case (Subbotin, 1969).

Concepts introduced by this idealization process have a great importance in science because of the simplifying function they perform. This makes it possible to construct theories that exclude those properties and relations of the object studied, which would only hinder the construction and the discovery of laws of the domain in question. It is hard to imgine how Newton would have discovered his law of gravitation without Kepler's idealized model of the solar system.

The quest for simplicity, however, conflicts with the quest for completeness. Hence the necessity of pointing out that the task of reverting from the statements of a theory developed on the basis of idealizations to the primitive real objects can involve great difficulties.

Idealizations as non analytic statements. This form of idealization is of much greater interest. It is really a convenient shorthand technique for referring to a complex set of connected conditions; for example, Boyle's Law and Galileo's Law (Barr, 1974). These idealizations have a profound effect in science because they have explanatory power.

Analysis of these idealizations (Rudner, 1966) shows that from a syntactical point of view they are indistinguishable from non-idealizations. Semantically, their outstanding characteristic is that they literally describe nothing. When they are involved in theoretical formulation these idealizations have the logical form of a universal conditional, that is to say, they are lawlike generalizations. However, the corresponding existential statement is false, therefore the universal lawlike statement is true but it fails to describe.

The great importance of idealizations in science is not apparent from their syntactical and semantic aspects, but only from pragmatic considerations. Theories have an explanatory role, and since most theories do not concern observations and measurements but idealizations (Bunge, 1973), it must be possible to show the explanatory status of idealizations in science.

The issues involved in the maning of explanation in science are extremely complex. This discussion will be simplified by taking the deductive-nomological view of scientific explanation. Briefly, according to this view, a singular event is explained if the explanans (which is composed of general laws and initial conditions) entails the explanandum (which is the statement describing the event being explained). Scientific theories, in particular idealizations, provide the lawlike statements constitutive of the scientific explanation. This is the role idealizations can and do play in explanations. (For worked out examples see Barr, 1974).

Stating the methodological task of idealizations still leaves the reasons for their success at this task unexplored. It is generally held (Subbotin, 1969) that it is not the idealization alone that has explanatory power, but the idealization embedded in a general physical theory. There are two special conditions that account for the successful use of idealizations in the physical sciences:

(a) the idealization is always subsumed under a more comprehensive theory with independent confirming evidence;

(b) the broader theories that encompass the idealizations give precise ways of comparing the actual with the ideal.

However, in traditional science courses these broader theories are not taught at the same time as the lawlike idealizations used in explanations. Therefore, the teacher is forced to produce phenomena that conform to the simple idealizations that students can learn. Under these conditions science becomes the study of laboratory phenomena and it loses all existential relevance. As Broudy (1973) says:

> The complacency with which science education promise that knowledge of science will result in applications of science should be shattered not only by the lack of correlation between scholastic achievement in science and technological competence, but the inability of even well-educated men to cope with the failures of their household applicances. Only the specialized technologist applied science to non-scientific activity. Science as a logically organized discipline is designed primarily for the study of science.

The analysis of idealizations presented above has shown their prevalence, importance and role in mature science. Therefore, they are important in the education of a scientific scholar. But implicit in the analysis is that the education of a person to theory in this disciplinary form leads ineluctably away from the existential relevance required for mass secondary education. This hiatus between the two models is implied in an important statement by Pippard (1972) when he became head of the Cavendish Laboratory:

> The beauty of physics and its enormous success spring from the recognition by generations of scientists that certain very simple abstractions may be made and analysed quantitatively to yield statements of crystalline perfection which we call Laws of Nature. But that success is bought at the price of turning our back on the infinite complexity that the real world presents to us. Therefore, we

> should not claim our discovery of fundamental laws to be an especially excellent achievement. The physicist, in contrast to most other intellectuals, has set himself a comparatively easy task, and the success with which he has accomplished it is at least as much a tribute to the simplicity of the task as it is to the intelligence of the worker.

Problem solving

The characteristics of the problems tackled in normal science have been described in a previous section. The problem-solving that students encounter from the start of their derivative science education, whether in laboratories, on examinations or at the ends of chapters in texts, share these same characteristics. The student is introduced both to the extraordinary perfection of the idealized laws of nature, as well as the fine collection of standard problems to which these laws can be applied to give the right answer.

The problems at the end of a chapter in a text must be a little artificial because they must be mathematically tractable, have right answers and have explanations under the idealized laws. However, they are usually written in such bland terms that the student fails to see how artificial they are. In other words, the style of both teaching and learning are discipline oriented, the teacher and student are involved in the objective discussion and solution of selected problems *within* the discipline.

This training in problem-solving seems hardly appropriate for mass secondary education where the problems, as well as having a scientific component, have social, moral and political components. Problems such as the pollution of the major rivers, urban living and transport, political implications of computers, etc. are problems requiring science and technology for their solution, but moral concepts for the choice of a solution, and political acumen for the realization of the solution. There must be training in problem-solving, giving due weight to non-disciplinary considerations.

Conclusion

The validity of the model of science education that has its origins in normal science is assured. Given the great confidence and pride that the scientists have in their paradigms and the enormous success of science, few scientists would wish to change the educational model. As Ziman (1971) says:

> I feel the need to preserve the collective skills, the expert knowledge, and the delicate social organization of the scientific community from the pressures of an ignorant public, a shameless press, rapacious money-makers and opportunist politicians.

This quotation is doubly significant because it appears at the conclusion of an article where Ziman has argued that scientists are "narrow specialists who are learned ignoramuses, unable to deal with the political and moral questions associated with science". These strictures have been applied to scientists by serious commentators for many years. Perhaps the way out of this dilemma that saves the model and answers the critics, is to follow up a suggestion of Bondi (1975). He thinks that physicists could be recruited like lawyers. Physics would not be taught at school; and the science education offered there would be a global study that involved the social, historical, moral and economic aspects of science. The introduction to the specific disciplinary paradigms and training in the special problem-solving skills would be undertaken at a later date.

In mass secondary science education the aim is to help people live happily and develop fully. The problems of technological progress that most people will be required to help solve are not, in the final analysis, capable of decision by the 'scientific method'. Such problems involve people in setting social priorities, making aesthetic judgements, and choosing material and spiritual standards. The inappropriateness of the traditional science education for the education of the typical citizen is beautifully summarized by Ziman (1968):

> Normal science is necessarily academic in a way that normal life should not and cannot be."

References

ASHBY, E. *The Bernal lecture 1971. Science and antiscience.* Proceedings of the Royal Society, London, B178: 29-42, 1971.

BARR, W.F. "A pragmatic analysis of idealizations in physics." *Philosophy of Science,* **41**(*1*): 48-64, 1974.

BUNGE, M. *Philosophy of Physics.* Reidel, Holland, 1973.

BONDI, H. "Physics, education and society." *Physics Education,* 469-474, November, 1975.

BROUDY, H.S. "Can research provide a rationale for the study of science." *Journal of Research in Science Teaching,* **10**(*3*): 227-233, 1973.

FEYERABEND, P.K. "Against method: Outline of an anarchistic theory of knowledge," in H. Feigl and G. Maxwell (Eds.), *Minnesota Studies in the Philosophy of Science,* **4**, 1970.

KUHN, T.S. *The Structure of Scientific Revolutions.* University of Chicago Press, Chicago, 2nd. ed., 1970.

PIPPARD, A.B. *Reconciling Physics with Reality.* Cambridge University Press, 1972.

RUDNER, R.S. *Philosophy of Social Science.* Prentice Hall Inc., New York, 1966.

SMOLICZ, J.J. "Fragmentation in science and education: An analysis of the community structure of science", in S. Murray-Smith (Ed.), *Melbourne Studies in Education 1974,* Melbourne, 1-58, 1974.

SMOLICZ, J.J. & NUNAN, E.E. "The philosophical and sociological foundations of science education: The demythologizing of school science." *Studies in Science Education,* **2**: 101-143, 1975.

SUBBOTIN, A.L. "Idealization as a method of scientific knowledge", in P.V. Tavanec (Ed.). *Problems of the Logic of Scientific Knowledge,* Reidel, Holland, 1969.

YOUNG, M.F.D. "Notes for a sociology of science education." *Studies in Science Education,* **1**: 51-60, 1974.

ZIMAN, J. *Public knowledge: The Social Dimension of Science.* Cambridge, 1968.

ZIMAN, J. "Social responsibility (1): The impact of social responsibility on science." *Impact of Science on Society,* **21**(*2*): 113-122, 1971.

SCIENCE AND PERCEPTION

Edward E. Nunan

Introduction

Underlying many recent interpretations of the nature of scientific endeavour are analyses of the act of perception. Formerly, this problem has been viewed from a philosophical standpoint, being concerned with the epistemological status of observation in science; newer approaches however have moved towards psychological and sociological explanations of perception as *underlying* the previous philosophical problems.

Thus the paper is not a philosophical exercise in the analysis of the role of 'percepts' in science; instead, it supplies a somewhat speculative analysis of the concept of perception as it is applied as an explanatory device in interpretations as to the nature of science.

This 'perceptual' feature of such recent approaches can serve as a common starting point to the interpretation of methodological frameworks which may help to signpost educational directives for instruction in science. Indeed, the stronger linking of scientific discovery to perception may foreshadow an 'anarchic epistemology of science', as perception may be highly idiosycratic. Feyerabend (1975) for example, appears to deny the possibility of even a praxiological research theory, advocating a 'hedonistic' approach to science.

Put bluntly, the implications of such investigations may reveal a mythology erected to suit the ideological needs of instructors; thus a methodology of science has been shaped to suit such pedagogic needs. One feature, the assumption of the triviality of scientific discovery (Ravetz 1973), has been fostered in accord with vague psychological notions concerning the nature of creativity.

The science-perception interface

Before attempting to discuss methodological issues, it will be necessary to outline the main writings concerned with the properties of the science-perception interface.

Because of the nature of this topic, sources have been quoted at some length; further, since debate in this area relies heavily upon 'philosophic' analysis, a number of specialized terms are used. To assist readers who may not be familiar with such terminology, definitions and explanations of terms have been collected into a footnote section appearing before the references of the paper.

As previously mentioned, the epistemological status of observation in science has been an area of concerned debate by philosophers of science. Popper (1968), for example, in expounding his anti-inductivist(1) theory cities in his *Logik der Forschung* Einstein's letter, where it is explicitly stated that . . .

> theory cannot be fabricated out of the results of observation, but that it can only be invented. (p.458)

This realization of the 'theory-ladeness' of observation has led to a search for factors which may interact with, or precondition observation.

Hanson's (1958) *Patterns of Discovery* details this problem employing a *psychological* interpretation. Indeed, he employs the gestalt(2) bird-antelope figure, predating Kuhn (1970) with his suggestions concerning the reorganization of conceptual fields resulting from scientific revolutions.

As Hanson cites . . . .

> Kepler and Tycho are to the sun as we are to (the gestalt bird-antelope figure) when I see the bird and you see only the antelope. The elements of their experiences are identical; but their conceptual organisation is vastly different. (p.18)

The *logical* interpretation of this dilemma posed by the status of observation is espoused by Popper who, in rejecting 'psychologism',(3) erects a logic of discovery; at the level of logic this approach tends to naive falsificationalism, but at a methodological level it demands a critical falsificationist stand.

Recently, the science-perception interface has been more fully explored in relation to scientific research; the impetus for such explorations has been provided by the suggestion that what happens in scientific research (discovery) is *not fundamentally different from what happens in immediate perception.*

Thus present conceptions as to the nature and methodology of science have drawn heavily upon the phenomena and language of perception in attempts to justify their interpretations. Kuhn, for example, uses a transactionalist(4) approach emphasizing gestalt concepts, citing the significance of Bruner and Postman's (1949) experiment 'On the Perception of Incongruity' . . . .

> Either as a metaphor or because it reflects the nature of the mind, that psychological experiment provides a wonderfully simple and cogent schema for the process of scientific discovery. (Kuhn 1970, 64)

Likewise, Polanyi (1969), in his essay on 'The Logic of Tacit Inference' assigns a *central* place to his concept of perception. As he states . . . .

> We must turn to the example of perception. This has been my basic assumption. I maintained that the capacity of scientists to perceive in nature the presence of lasting shapes differs from ordinary perception only by the fact that it can integrate shapes that ordinary perception cannot readily handle. *Scientific Knowing consists in discerning gestalten that indicate a true coherence in nature.* (p.138)

Polanyi (1969), like Kuhn, links the perceptual process with scientific discovery . . . .

> While the integration of clues to perceptions may be virtually effortless, the integration of clues to discoveries may require sustained efforts guided by exceptional gifts. But the difference is only one of range and degree: the transition from perception to discovery is unbroken. *The logic of perceptual integration may serve therefore as a model for the logic of discovery.* (p.139)

Thus, to Polanyi (1969), scientific discovery is best explained in perceptual terms . . . .

> a scientific discovery reduces focal awareness of observations into a subsidiary awareness of them, by shifting our attention from them to their theoretical coherence. (p.140).

It is this act of integration, demonstrated in visual perception, which provides the clues to his theory of tacit knowing.(5)

Lorenz (1974) on the other hand, relates a more behaviouristic approach linking the *physiology* (rather than psychology) of perception with Popper's doctrine . . . .

> in the physiology of perception it is found everywhere, and in the conscious thinking of man it takes the form of conjecture and consequent confirmation . . . . . In Science these processes are called hypothesis formation and verification. (p. 58)

Further, Bohm (1970) also cites psychological sources on perception as the starting point for his ideas concerning holocyclation and procedation. Holocyclation, he maintains . . . .

> is the fundamental description of perception, while analysis into procedative steps of separate parts or aspects is at most a useful abstraction. (p. 2)

Characteristic of Bohm's approach is the return to fundamentals and the proposal of an alternate language which more appropriately describes what he regards to be the basic features of perceptual processes. Thus the term holocyclation is coined in attempt to draw attention to a fundamental feature of perception; 'holo' is used to describe the integrative or whole features of the perceptual act, while cyclation indicates a non-static view stressing the relationship of the parts to the whole while including the concept of 'undivided movement' of the parts comprising a whole.

It is not surprising that the artist also makes contributions to the understanding of the science-perception interface. Being professionally concerned with perceptual involvement and its interaction within the subject-object relationship, it is not unexpected that the artist should assume a 'special' observer status when he supplies perceptual insights which relate to the nature of science. For example, Herrmann (1974) recounts of Husserl's phenomenology . . . .

> our attitude towards science must be grounded in a transcendental,(6) constitutive(7) phenomenology. Husserl did not question the validity of science, its methods, and its techniques. What he criticized about the methodological ideal of science was its most artificial character. Science, he held, has a pre-conceptual background: it is *founded in our sense perception*, and the fundamental procedure used to analyse this sense perception in all its facets is the 'phenomenological method'. This method opens up everything registered in human consciousness, be it a dream, memory or reflection.

Dubos (1970) further points to the 'anaesthetising' of our perceptual modes due to the effects of science and technology, and like Husserl suggests that a return to 'primordial' forms of perception will halt our present scientific alienation from the emotional ties of Nature.

Thus many present studies concerning the science-perception interface are broadly based and suggest far reaching implications. By contrast, previous studies in this area tended to be much narrower, falling within the province of the science-oriented philosopher.

In interpreting the problems of science as a sub-set of wider philosophical problems, the science-oriented philosopher used epistemological studies to comment upon percepts and sensations as a basis for scientific knowledge (Harre 1972). Such studies have used philosophic systems to guide interpretations; for example, the metaphysical theory of phenomenalism which is based upon the study of sensations and not with the things which cause us to experience sensations, can be used in interpreting scientific knowledge.

Thus, philosophic analysis has provided a traditional strand to the study of perception and has consequently impinged upon interpretations of science. What is now of considerable interest is that the parallel strands to the study of perception provided by physiological/neurological and psychological/learning approaches underlie newer studies. That is, the study of the science-perception relation is now being considered in a much wider context – discussion on the 'absolute objectivity of observation' and the like, have yielded to psychological/philosophic studies broadly concerned with meanings associated with "seeing". One has only to make a quick reading of Kuhn (1970) (for example) to appreciate the underlying 'perceptual bias'. In line with his gestalt approach Kuhn applies the terminology of perception . . . .

> after the assimilation of Franklin's paradigm, the electrician *looking* at a Leyden jar *saw* something different from what he has seen before. The device *had become* a condenser. . . . . (p. 118)

Further examples abound . . . .

> Lavoisier . . . . *saw* oxygen where Priestly had *seen* dephlogisticated air and where others had seen nothing at all. (p. 118)

This reliance upon underlying perceptual terminology has led to criticism that Kuhn employs a conceptual scheme which has a 'sudden and unstructured event' playing the central role. Not unexpectedly, such a scheme has been severely criticized by philosophic analysis: as Kordig (1971) notes . . . .

> After the assimilation of Franklin's paradigm the electrician looking at a Leyden jar did *not* see sumething different. The device did not become a condenser. Rather, it was not believed (or known) to possess new properties, condenser properties. Different features of what was seen were now believed to be more important. Their importance was due to their now more central relation to the new conceptual frame-work. Shifts of vision *are* shifts of *vision*, not belief. No profit results from an inordinate intertwining of these concepts. Sight is one thing, belief another. The same holds for dephlogisticated air versus oxygen. . . . . (p. 18)

Kuhn (1970) explicitly counters this philosophical approach – sight and belief are intertwined . . . .

> though they are always legitimate and are occasionally extra-ordinarily fruitful, questions about retinal imprints or about the consequences of particular laboratory manipulations presuppose a world already *perceptually* and conceptually subdivided in a certain way. (p. 129)

Kuhn sees scientists epistemologically locked into a paradigm *via* his perceptual modes. Like Wittgenstein, he criticises the possibility of drawing a line between the empirical and the conceptual; indeed, this same indeterminacy remains as a fundamental problem to interpretations as to the nature of perception (Phillips (1975)).

Philosophic studies have neglected the very point that transactionalist and gestaltist studies have made central – that is, what is perceived is not determined by the physiological stimulus pattern, but is based upon meanings placed upon previous perceptual transactions with the environment. Polanyi, too has emphasized this feature, pointing out the operation of an overriding effort to *rationality* in our perception; Ames' work on perceptual constancy illustrates the operation of this feature.

Thus it is suggested that the essential indeterminacy between the empirical and the conceptual (or in alternate guises between observation/theory, discovery that/discovery how, induction/deduction) is paralleled in the perceptual process. In moving problems of scientific discovery to this underlying perceptual position a new set of fundamental dilemmas result – those introduced by our vague understanding of the nature of perception.

Perception research

We have so far merely pointed to links between concepts of perceptions and interpretations as to the nature of science. Further to attempt to judge the worth of such perceptual evidence as used by commentators as to the nature of science (Kuhn, Polanyi, Bohm, Hanson) we need to consult the specialist literature associated with perception to ascertain the professional status given to such experiments.

For the case of Polanyi, of course, we must also move outside of 'conventional' perception studies to encompass not only *per*ception but also *sub*ception. However, this approach is strongly linked with a more 'conventional' school, for subception, in Polanyi's (1969) view, is connected with a gestalt approach (p. 143).

It is especially significant that the specialist literature of perception reveals competing 'schools' of thought. Reminiscent of a Kuhnian description of pre-paradigm science, we find each school highlighting as significant, the phenomena that are explicable in their terms. A further interesting aspect is that this fragmentation of the study is not only limited to the 'competing schools' stage – it would appear that a general 'pre-conceptual' fragmentation is evident, with researchers not only questioning the tenets of other conceptual positions, but ignoring their own theoretical foundations in returning to 'basic' empirical research. On this aspect, Day in the (1964) *Annual Review of Psychology* comments . . . .

> after close scrutiny . . . . in an area in which there is not yet agreement regarding definition, one is impressed mainly by two important trends: (a) the increasing concern with methodological issues, ... and (b) the development and testing of restricted theories *independently of the main* theories of perception. This second trend has largely guided the direction which this review has taken. *One wonders if the latter tendency is fruitful.* There remains the nagging thought that either the major theoretical models should expand to encompass material so far unconsidered or the more restricted theories should be considered in relation to the major positions.

Indeed, Day's (1964) comments would still seem to be of relevance today as . . . .

> often it is still difficult to ascertain whether a particular experiment is the consequence of a theoretical position or alternatively an empirical investigation to a specific area without reference to a general theory.

Norman (1971), however, considers that a new over-riding consensus will arise from human-information-processing approaches to the study of perception; this approach is consistent with the 'revolution brewing in psychology' where 'we admit the existence of mind, and of images, thought, imagination and the subconscious'.

After the abandonment of the Functionalist, Psychophysical, Stimulus Response and Phenomenalist 'school research', perceptual studies generated a wealth of restricted empirical results focussing upon *special* and *specific* problems such as perceptual constancy, after effects, illustory effects, perceptual development, perception of form, pattern, motion and time, signal detection, and temporal factors. Norman's comments reflect a movement back to the wider problems of perception – indeed, a return to perception being considered again within a 'learning context'.

However, it is not at all clear that Norman's optimism is warranted; apart from significant advances in the neurology, physiology and anatomical studies concerning perceptual processing it would appear that any significant consensus upon explanatory features of models is still lacking. Along these lines we find current overviews returning to 'key themes' which still feature *fundamental* conceptual problems (Held, 1972). Thus, Norman's 'perceptual vectors' could appear to be little more than 'modern' terminology for Descartes 'feature detectors'.

While Day points to increased concern with methodological issues in his 1964 review, it would appear that his later text showed no sign of Norman's brewing revolution; although two years earlier than Norman's article, instead of taking a 'humanistic psychology' stand, Day (1969) summarizes the arguments against the classical Wundt position and finds . . . .

> Overriding all these considerations, however, was an increasing demand for an emphasis on precision and quantification in experiment which was not obtainable using introspection. *It was for this last reason that psychophysics eventually triumphed as the basic procedure for the study of perception.* (p. 25)

Though the extreme forms of psychophysical approaches to perception are tempered by current systems approaches there is, nevertheless, a reliance upon behavioural language, communication and computer models of information processing and psychophysical-neurological studies (Held 1972).

Interestingly these very features of current perception research are deemed irrelevant or ignored by studies relating to the nature of science. Comment on the nature of science as 'derived' from perception studies uses perception research which, in broad terms, rejects the 'scientific' psychophysical approach and relies upon perception being viewed within a 'learning context'. Further, interpretations of the nature of science which include perception research are generally sensitive to the philosophical implications or aspects of their position.

Kuhn, for example, well illustrates this approach; the Postman and Bruner experiment is concerned with 'perception as something the organism does' and is not primarily psychophysical; the result is interpreted within a 'learning context' and Kuhn is indeed sensitive to the philosophical interpretations. Like transactionalist approaches, Kuhn avoids solipistic implications by refusing to regard perceiver and perceived as separately given; the proper philosophic starting point must then be the 'transaction' between perceiver and perceived and the act cannot be further analytically resolved.

Indeed, Kuhn's position moves towards applying the concept of *praxis*. As Ingleby (1972) points out . . . .

> While *process* describes the behaviour of inanimate objects, accounted for wholly by causes, praxis is the medium of the specifically human: it implies behaviour which is purposive and accountable for only in terms of its meaningfulness (whatever may be said about its causes). Moreover, human behaviour is based upon human experience, through which it is related to an external content: and such experiences, as the phenomenologists have emphasized, is itself praxis rather than process, being an active selection and structuring of sensory information. Praxis is thus a composite notion, referring to the activities of perception as well as behaviour, and bringing together the ideas of purposive (goal-directed) activity as well as communication. (p. 58)

This attempt to view empirical phenomena as *more than process* illustrates the break from psychophysics.

General implications

The previous section points to features of the study of perception as they might relate to interpretations of the history of science. We have seen that, in general, the fragmentation displayed by studies in perception have allowed suggestive interpretations in relation to science.

However, Kuhn and Polanyi, it would appear, follow the problem of perception to areas *outside* of current professional concern. Polanyi attempts to cite subception research as providing a suggestive justification for his position while Kuhn, in effect, may be implicitly relocating perception back into a sociological context. As Douglas (1973) notes, that apart from Merleau Ponty's work, the theory of perception seemed to become thereafter mainly a concern of psychology, *not of sociology* (p. 10).

The significance of Merleau Ponty's (1964) work, especially the area of the philosophy and methodology of science is yet to be extensively explored. Polanyi (1946) for example in *Science Faith and Society* expresses the opinion that Merleau Ponty's *La Phenomenologies de la Perception* 'arrives at views akin to those I have expressed here' (p. 12). The relevance of perception studies to studies in the nature of science is seen by Merleau Ponty (1964) in the following terms . . . .

> . . . . it seems to me that the acquisitions of the philosophy of the sciences confirm the *primary of perception*. Does not the work of the French school at the beginning of this century, and the work of Brunschvicq, show that scientific knowledge cannot be closed in on itself, that it is always an approximate knowledge, and that it consists in clarifying a pre-scientific world the analysis of which will never be finished.

Thus the outlining of the features of the organic tie between perception and 'intellection' becomes a central feature – perception and thought to Merleau-Ponty (1964), reveal common features. It is the *primacy* of perception, that is significant. By primacy . . . .

> we mean the experience of perception is our presence at the moment when things, truths, values are constituted for us: that perception is a nascent *logos*; that it teaches us, outside all dogmatism, the true conditions of objectivity itself; that it summons us to the task of knowledge and action. It is not a question of reducing human knowledge to sensation, but of assisting at the birth of knowledge, to make it as sensible as the sensible, to recover the consciousness of rationality.
> . . . . (p. 25)

Such a viewpoint places the study of perception at the fore-front of studies as to the nature of science.

The study of perception, however has yet not been able to reveal the sought after 'organic tie' between perception and intellection. Consequently, the pluralistic approaches and the speculative analyses generated by the application of fragmented perception studies to the nature of science warrant close attention. In this light, Bohm's 'radical' description of perception becomes less of an interesting aside and may undertake fundamental importance.

Thus we find the need to re-examine studies such as Bohm's. The concept of holocyclation, by providing a fundamental description of perception, requires further analysis – other empirical studies might be fruitfully re-interpreted applying Bohm's terminolgies. Indeed Smolicz (1974) has provided an analysis of the significance of Bohm's ideas in relation to both the scientific communities and the esoteric knowledge which they generated; he has also extended this approach by linking Bohm's conceptual position with Kuhn's work.

Thus work in this area is beginning to show some sign of contributing to an understanding of the nature of science; however, the link, at present displays a tenuousness, calling for a pluralistic approach.

Methodological implications

To return to the problem of signposting methodological directives for instruction in science, it is now apparent that any guidelines extracted from analyses of the science-perception interface will be only of a tentative nature. It is in this area that suggestions may be described as *unabgesichert* – that is, insufficiently protected from critical attacks. However, it would appear that the previous analysis could be speculatively extrapolated, generating a number of fundamental considerations.

In terms of our previous analysis it appears that if revolutionary type discoveries depend upon unique perceptions brought about *via* a sudden 'gestalt' switch, then concern for discovery in this sense provides a futile exercise for development of an instructional methodology. Put simply, when science educators are talking about discovery, they cannot be considering this fundamental 'perceptual' aspect of science – instead, their concern is for the pedagogical connotations developed for the term discovery. Thus, for revolutionary discovery we can side with Feyerabend and deny 'method' in science.

Further analysis of this problem of 'discovery' leads us to consider 'discoveries' which are non-revolutionary. While Ravetz (1973) is of the opinion that the Kuhnian dichotomy is too sharply drawn it would appear that it would be foolish to ignore the idea of "two sciences" (revolutionary and normal).

Thus revolutionary type discoveries, as we have seen, largely defy method – the source of difficulty for discussion of method lies in the attempt to render explicit that which is largely tacit. The interpersonal channels necessary for the transmission of such craft-knowledge *exclude* formalized instructional techniques. Can we then postulate a weakened 'discovery' of essentially the same kind as 'revolutionary' (but in a much diluted form) as the type of discovery which characterizes normal science?

The Kuhnian answer here is that there is a difference in kind – discovery within normal science is akin to perceptual categorisation, of ordering and sense making within an essentially pre-structure field. We are now faced with the question of whether a 'methodology' can be derived for scientific instruction in this form of discovery.

The Kuhnian analogy of 'puzzle-solving' can be suggestively related to perceptual research. Such research stresses that perception is not a passive "taking-in" process, but instead is an active pattern seeking process, closely allied to the act of thinking. In terms of perceptual learning one need only cite the 'closure' phenomenon of "filling in" and "finding" patterns against a particular background. The scientific paradigm provides cues to closures (*i.e.* puzzle solving and pattern producing) in science.

The scientist is generally indoctrinated into the perceptual expectations of a paradigm during secondary and university education. As Polanyi (1946) notes,

> school science imparts a facility in using scientific terms to indicate the established doctrine, the dead letter of science. The university tries to bring this knowledge to life by making the student realize its uncertainties and its eternally provisional nature, and giving him perhaps a glimpse of dormant implications which may yet emerge, from the established doctrine.

Thus if we measure discovery in terms of "closure" of puzzle situations we may search for such manifestations in science education. Clearly, at a school level, "discovery" in this sense could only be viewed as a "closure" of essentially the same kind as that of a normal science discovery. It is at this level that the Brunerian notion that the schoolboy learning physics *is* a physicist is simplistic; intellectual activity at the frontier of knowledge, at the 'normal' scientists workbench, or in a third grade classroom is *not* a difference of degree.

The only real similarity between normal science discoveries of the scientist and the school or university student lies in the idea that both cases can be subsumed under the concept of perceptual closure. Again, even for 'closure' type discoveries, perceptual research suggests that no methodology exists – 'closure' *events* are, *a priori*, the phenomena of perception.

Put simply, the argument, is against the possibility of a methodology even at this level. What directives are currently applied in science education would seem to stem from *psychological* rather than philosophical or historical sources.

Returning to the original contention of this paper it is suggested there are indeed features of scientific research (discovery) which are not fundamentally different from what happens in immediate perception. However, as Polanyi notes, while there exist strong parallels, scientific perception cannot be equated with ordinary 'visual' perception – scientific knowing consists in discerning a special gestalten, one which requires 'integrative' abilities beyond that of visual perception.

No methodological directives follow from any *logic of perceptual integration*. Scientific education must therefore contain within it a tacit component; explicit accounts of methodology, of scientific method and the like, represent but no more than flickering shadows of a 'scientific reality'.

Perceptual analysis then suggests an absence of 'method' in science. Thus the mechanics of instruction in science might be organised on a number of conceptual (structure of content) or psychological schema (properties of the student) but cannot be distilled from the *practice* of scientists.

Footnotes

(1) *inductivism:* Whereas inductivism holds that 'our degree of belief in the truth of law is proportioned to the number of favourable instances', Popper's position allows 'no logical relations between favourable evidence and hypotheses, other than the fact that a piece of favourable evidence represents a failure to falsify a hypothesis' (see, for example, R. Harre, (1972)).

(2) *gestalt:* Gestalt psychology has been most successful in the area of perceptual learning. Gestaltists showed that perceptual fields were organised in terms of outstanding wholes (configurations or *gestalten*) which stood out against the background of the remainder of the perceptual field. Gestalt switching occurs when the figure and ground are approximately equal and is characterized by an alternating reversal of the figure ground relationship (see, for example Heider (1973)).

(3) *psychologism:* Popper defines psychologism as the doctrine that statements can be justified not only by other statements but also by perceptual experience. Psychologism contains within itself a subjective uncertainty; to remove this psychological factor Popper proposes an objective theory of essentially conjectural knowledge. Knowledge in an objective sense is Knowledge without a Knower. Popper (1968).

(4) *transactionalist:* Transactional analysis studies *transactions* between objects – phenomena are studied as a totality or field where the interrelatedness of events is taken into account. The emphasis is not on the observation of static things but upon the dynamics of relationships between objects.

(5) *tacit knowing:* Polanyi bases his ideas of tacit and explicit knowledge upon an analysis of perception. The act of integrating focal and subsidary awareness (related to figure and

ground of an object) is tacit knowing. In many aspects tacit knowledge and explicit knowledge (knowledge of rules and procedures) are opposed (see, for example, (Polanyi 1969)).

(6) *transcendence:* To Husserl, transcendence begins with the meaning of objects.

(7) *constitutive:* A term used in the sense that meaning is constituted in and through consciousness.

phenomenology: To the founding father of phenomenology (Husserl) the study attempts to deal with the subjective component of knowing, or the way that we confer meaning upon the world (see, for example Poole (1973) or Kockelmans (1969)).

References

BOHM, D. "Fragmentation in science and society." *Impact of science on society*, **10**, *1970*.

BRUNER, J.S. & POSTMAN, L. "On the perception of incongruity: A paradigm." *Journal of Personality*, **18**: 206-23, 1949.

DAY, R. "Perception." *Annual Review of Psychology*, (California), **15**: 1-27, 1964.

DAY, R. *Human Perception*. Wiley, Sydney, 1969.

DOUGLAS, M. *Rules and meanings: The anthropology of everyday knowledge*, Penguin, Middlesex, 1973.

DUBOS, R. *So human an animal*, Abacus, London, 1970.

FEYERABEND, P. "How to defend society against science." *Radical Philosophy*, **11**: 3-8, 1975.

GIBSON, J.G. *Psychological Review*, **69**: 477, 1962.

HELD, R. & RICHARDS, W. *Perception: Mechanisms and models*. Scientific American Review Publications, San Francisco, 1972.

HEDER, F. "Gestalt Theory: Early history and reminiscences", in Henle, M., *Historical conceptions of psychology*, Springer, New York, 1973.

HANSON, N.R. *Patterns of discovery: An inquiry into the conceptual foundations of science*, Cambridge University, Press, Cambridge, 1958.

HARRE, R. *The philosophies of science*, Oxford University Press, Oxford, 1972.

HERRMANN, R. "Art, technology and sense perception." *Impact of science on society*, **24**(*1*): 89-99, 1974.

INGLEBY, D. "Ideology and the human sciences: Some comments on the role of reification in psychology and psychiatry", in T. Pateman (Ed.) *Counter Course*, Penguin, Middlesex, 1972.

KOCKELMANS, J. *The world in science and philosophy*. Bruce, Milwaukee, 1969.

KORDIG, C.R. *The justification of scientific change*. Reidel, Dordrecht, 1971.

KUHN, T.S. *The structure of scientific revolutions*. University of Chicago Press, Chicago, 2nd. Edit., 1970.

LORENZ, K. *Civilized man's eight deadly sins*. Methuen, London, 1974.

MERLEAU-PONTY, M. "The primacy of perception and its philosophical consequences", in J. Edie (Ed.), *The primacy of perception (and other essays)*, North Western University Press, USA, 12-42, 1964.

NORMAN, D. "Human information processing." *Viewpoints*, **47**(*4*): 48-65, 1971.

PHILLIPS' D.L. "Paradigms and incommensurability." *Theory and Society*, **2**: 37-61, 1975.

POLANYI, M. *Science, faith and society*, University of Chicago Press, Chicago, 43, 1946.

POLANYI, M. "Knowing and being", in Grene, M. (Ed.) *Knowing and being: Essays by Michael Polanyi*, Routledge & Kegan Paul, London, 1969.

POOLE, K. *Towards deep subjectivity*. Allen Lane, London, 80, 1973.

POPPER, K.R. *The logic of scientific discovery*, Revised Edition, Hutchinson, London, 1968.

RAVETZ, J.R. *Scientific knowledge and its social problems*, Penguin University Press Middlesex, 115, 1973.

SMOLICZ, J.J. "Fragmentation in science and education: An analysis of the community structure of science", in S. Murray-Smith (Ed.) *Melbourne Studies in Education*, Melbourne, 1-58, 1974.

THE EFFECT OF VARYING THE MODE OF PRESENTATION OF ASEP MATERIALS ON PUPILS' PERCEPTIONS OF THE SCIENCE CLASSROOM

Jeff. R. Northfield

Introduction

The Australian Science Education Project (ASEP) has provided a significant stimulus for educational research in Australia (Owen 1975). The nature of the curriculum materials, with their emphasis on the activities in the science classroom and the science teacher's role in the classroom have required a re-examination of approaches to curriculum evaluation. Zoller and Watson (1974) have provided an analysis of "second generation" science curricula and their description seems to apply to many of the stated objectives of the ASEP project (ASEP 1974). In particular the Australian curriculum is clearly based on an understanding of and a catering for individual differences in pupils. The emphasis on the learning environment and the role of the teacher, so evident in the ASEP approach (see Part Three, Education Theory, in ASEP (1974)) has meant that learning environment variables have been included in evaluation studies reported to this stage (Fraser 1975, Tisher and Power 1975).

The learning environment has been the subject of increasing interest in educational research. Randhawa and Fu (1973) report extensive use being made of pupil self report inventories such as the Learning Environment Inventory (L.E.I.) to study classroom environment questions.

There seems to be several important reasons for the increasing use being made of student self report inventories such as the L.E.I.

1. The inventories/questionnaires are easy to administer and provide an economical way of gathering data bout the classroom.
2. Student responses are claimed to provide a realistic way of assessing the environment:

> the student is the intended recipient of instruction cues in the classroom, particularly social stimuli; and he may be the best judge of the learning context. Compared with a short term observer he weighs in his judgement not only the class as it presently is but how it has been since the beginning of the year . . . . He and his classmates form a group of twenty or thirty sensitive, well informed judges of the class., An outside observer is a single judge who has far less data and, though highly trained and systematic, may be insensitive to what is important in a particular class.
>
> (Anderson and Walberg, 1974, p.86.)

3. A number of studies using the L.E.I. have shown it to be a significant predictor of important learning outcomes (Anderson and Walberg 1974, Fraser 1975). In this case the L.E.I. sub-scales are being used as independent variables.
4. Initial characteristics of the class can be used to predict the learning environment (Anderson and Walberg 1974) so providing some hope of controlling the climate to some extent.
5. Walberg (1971) provides a reason for studying the classroom environment from his model of learning. He argues that three groups of variables contribute to learning, aptitude variables, instructional variables and environmental variables. Of these three groups only the

latter are subject to manipulation to alter the learning outcomes. Accepting this model, it is interesting to think about how the environment might be "manipulated" to improve learning.

Getzels and Thelen provided the framework for the L.E.I. development in their sociological analysis of the classroom climate (Getzels and Thelen 1960). A closer examination of the Getzels and Thelen model can indicate the possible sources of manipulation of the learning environment. Figure 1 shows part of this model and indicates that classroom climate is seen to be a unique combination of the individual personalities in the classroom group and the roles each individual is expected to play in science classes.

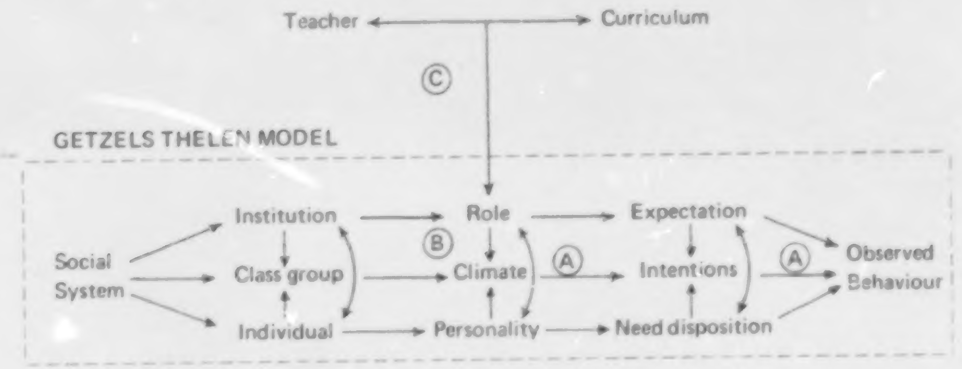


FIGURE 1: Rationale for curriculum emphasis on learning environment variables

The ASEP emphasis on classroom climate can be considered as occurring via a description of suggested roles that teachers and pupils could occupy in ASEP classrooms. Fig. 1 therefore provides a rationale for a curriculum emphasis on classroom climate, an emphasis that will be useful if three conditions are met.

1. The classroom climate variables must continue to be shown to predict the desirable outcomes of the cirriculum (Step A in Fig. 1).

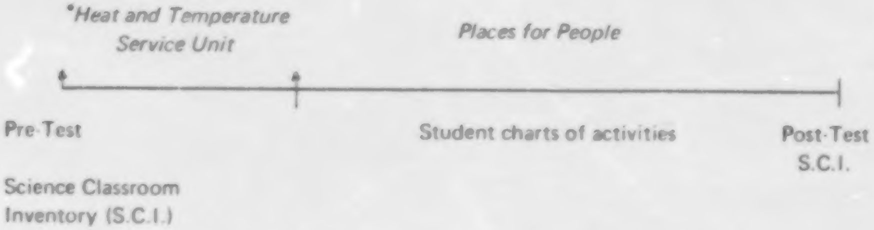
2. Evidence will need to be provided that the roles being suggested for pupils and teachers in science classes result in the desired classroom climate (Step B in Fig. 1).

3. Approaches to teacher education will need to be developed which enable teachers to understand (and perhaps adopt) the roles of teacher and pupil being suggested by the materials (Step C in Fig. 1).

Many of the studies of ASEP have been dealing with questions which could be classified into one of the three areas stated above. This study is concerned with the second area as it attempts to look at the effect of different methods of using the ASEP materials (differing roles of teacher and pupils) on the classroom climate (as perceived by the pupils).

Design of the study

At the beginning of Term III (September 1974) 23 Grade 7 science teachers were invited to use the ASEP unit *Places for People.* At an initial individual interview each teacher was given a copy of *A Guide to ASEP* (ASEP 1974), a class set of the student books for the unit, and a class set of the associated service unit *Heat and Temperature.* The design of the study was made clear (see Fig. 2) but it was stressed that teachers were to make their own judgements as to how the materials were to be presented, and how much time they might spend on the units.



* Teachers were informed that only pp. 1-19 of the service unit contained information directly relevant to the unit *Places for People.*

FIGURE 2. Design of the study

Instruments in the study

The Science Class Inventory. The Science Class Inventory (S.C.I.) is a modification of the L.E.I. (Anderson 1971) for Grade 7 students. The sub-scales developed were those that seemed to represent important aspects of classrooms where ASEP materials were being used. Each of the sub-scales were justified on the basis of emphasis in *A Guide to ASEP* (ASEP 1974). In some cases the names of the sub-scale have been altered from the original L.E.I. to names that better reflect the classroom dimension being described in this study. The instrument was trialled to check for language difficulties and ineffective items.

Some details of S.C.I. are set out in Table 1. Students were required to respond by circling one of four alternatives: strongly disagree (SD), disagree (D), agree (A), strongly agree (SA), and these were scored 2, 4, 6 and 8 respectively for a positive item (showed (+) in Table 1) and 8, 6, 4 and 2 for a negative item (shown (-) in Table 1). No response or multiple responses to an item were scored 5.

The Student Charts. Each student in each class kept a record of his/her activities by filling in a chart at the end of each lesson. One of the tasks was to tick the parts of the unit that had occupied more than 5 minutes of his/her time during the lesson. At the end of the unit it was possible to collate the information from each student into a pattern of the way the unit was presented in each class. For this part of the study an estimate of the number of different activities for each lesson in each class was made. For this estimate, any part of the unit on which two or more students had worked in a lesson was counted as an activity. The mean number of activities per lesson was then calculated for each class, and for the purposes of this calculation, the first lesson and last lesson were excluded. (It was argued that the first lesson would be likely to involve time in organization and perhaps the last lesson time in cleaning up, starting the next piece of work, etc.)

TABLE 1

Details of S.C.I. Sub-Scales

Sub-Scale (Name of similar L.E.I. Scale)	Sample Item	Cronbach Alpha	No. of items in Sub-Scale
Formality	* Students follow strict rules in science classes. (+)	0.53	5
Individuality	* Pupils can choose to study different science topics that interest them. (+)	0.55	6
Speededness (Speed)	* The work in science is covered too quickly. (+)	0.72	5
Environmental Suitability (Environment)	* Science lessons are held in a room which allows us to carry out our science activities easily. (+)	0.70	6
Goal Directedness (Goal Direction)	* Students have little idea of what the real point of studying science is. (-)	0.66	6
Satisfaction	* After the class, the students feel science lessons are worthwhile. (+)	0.83	6
Disorganization	* There are long periods during which some class members do not know what to do. (+)	0.74	6
Difficulty	* The questions asked in science are often difficult. (+)	0.48	6
Competitiveness	* Students often race to see who can finish first. (+)	0.60	5

Four of the classes could not be included in this part of the study. Two classes had used the materials as part of a general studies programme and the student charts did not provide information which had the same meaning as the other classes. Two other classes had small class sizes which made comparison with other groups of doubtful value. With respect to the mean number of activities per lesson, the remaining 17 schools were seen to form three groups (see Table 2).

TABLE 2

Mode of implementation and mean number of activities

Mode of Implementation	Mean no. of Activities/Lessons	Range
1. Wide student choice (5 classes)	8.7	7.8 to 9.7
2. Less student choice (5 classes)	7.0	6.8 to 7.3
3. Limited student choice (7 classes)	4.6	2.2 to 5.8

Method of analysis

In a number of studies using the L.E.I. sub-scales as dependent variables, a number of predictors of classroom climate have been reported (Anderson and Walberg 1974, Walberg and Ahlgren 1970). Although it was intended that this study examine the effect of mode of presentation on classroom climate, it was necessary to also consider other variables that may be affecting the learning environment. Previous studies have indicated that classroom climate is likely to be affected by curriculum, class size, grade level, girl ratio, socio-economic status and ability level. The study design controlled the first four groups of variables to some extent (A particular ASEP unit used in Grade 7 co-educational class in Victorian high schools); S.E.S. has been shown to be associated with students' response to "competition" items. No attempt was made to control this variable in this study. Ability level has been measured in several ways in past studies (cognitive pre-test, I.Q., grade point average, etc.). Ability level seemed to predict difficulty, disorganization, speed, formality and goal direction (Anderson and Walberg 1974). No design control was attempted in this study but it seemed to be important to check whether ability level was a significant factor in students perception of the learning environment. This was attempted by asking teachers to indicate:

(a) the students who appear to have most ability in science;
(b) the students who have the most difficulty in science at the end of the unit.

The method of analysis chosen was that described for a three factor experiment with repeated measures on one factor Case 11 (Winer 1971, p. 559). The unit of analysis in this case was taken to be the ability sub-group within each class. Fraser (1975) has previously presented arguments for using the sub-group within a class as the unit of analysis and this question of unit of analysis, though important, will not be developed further in this paper. The cell sizes (5, 5 and 7) required an unequal cell size solution and the unweighted means solution was used in this analysis (Winer 1971, p. 600).

Results

The results of the analysis are set out in Table 3. Before examining the results it is

TABLE 2

Result Summary

Anova Summary

Dependent Variable

Source	df	Formality	Individ.	Speed	Envir. Suitability	Goal Dir.	Satis-faction	Disorg.	Difficulty	Com-petition
Mode of Implementation A	2,42	2.33 NS	7.27***	5.59**	1.72 NS	3.42*	4.68*	3.68*		
Ability Level B B	2,42	1.90 NS		4.81*		2.30 NS			2.01 NS	
Time C	1,42	([illegible])2.61 NS	(+)17.41***		(-)2.49 NS	(+)5.02*	(-)7.67**		(-)5.83*	(-)16.62***
A x B	4,42		1.27 NS							
A x C	2,42				3.56*	1.50 NS	2.13 NS	2.58(*)		
B x C	2,42			1.74 NS						
A x B x C	4,42			1.55 NS						

		(*) 0.10	* 0.05	** 0.01
F_{crit}	2,42	2.43	3.22	5.15
	1,42	2.83	4.07	7.27
	4,42	2.08	2.59	3.80

necessary to indicate one more piece of information. Winer (1971) outlines two assumptions associated with the experimental model used in the study. In the case of our sub-scale (Difficulty) the assumption of equality of variances was not satisfied and in a further sub-scale (Disorganization) the assumption related to symmetry of the variance covariance matrix was not satisfied (Winer 1971, p. 594). The results associated with these two sub-scales must therefore be examined with some extra caution.

Some of the significant findings are represented in graphical form in Figure 3.

Interpretation of the results

At the end of the period in which the ASEP unit *Places for People* and its associated service unit was used with these 17 Form 1 classes there has been an overall increase in Individuality and Goal Directedness and an overall decrease in Satisfaction, Difficulty and Competition (Main Effect C in Table 3).

In one sub-scale the F value for the A x C interaction (Mode of Implementation and Time) reached significance at the 5% level. Figure 3(3) illustrates this interaction – the classes in which a large number of activities occurred showed a slight increase in environmental suitability while the classes with very few activities per lesson showed a decrease in environmental suitability. Teachers who allowed a wide range of activities in each lesson seemed to also arrange the physical conditions to facilitate the diversity of activities. The physical conditions appeared less suitable in classrooms where ASEP was used with more restricted student choice occurring.

The main effect A (Mode of Implementation) provided significant F values in five of the nine sub-scales. In this case the comparison is being made between the average of pre and post values for each mode of implementation. Examination of Figure 3(4) indicates that overall Group 2 (less student choice – Table 2) reports science as more goal directed. Inspection of the student diaries for this group of classes revealed a pattern of a limited number of student activities in the early lessons but a larger number of student activities near the end of the unit. In examining the plots in Figure 3, this pattern of presenting the unit needs to be kept in mind for this group of classes.

The effect of ability level was shown to be significant in the case of Speededness. The overall effect of ability level is illustrated in Figure 3(2).

Concluding comments

This study has attempted to examine the relationship between one aspect of the implementation of an ASEP unit and students' perception of the learning environment. With the introduction of science curricula which suggest appropriate roles for teacher and pupils it seems necessary that the effect of different methods of implementation on the resulting learning environment be investigated. The teacher education associated with ASEP has sought to make teachers aware of appropriate roles for teacher and pupil to occupy when using ASEP materials. Empirical evidence related to the effectiveness of various methods of implementation may be useful in further clarifying the arguments for using the materials in particular ways.

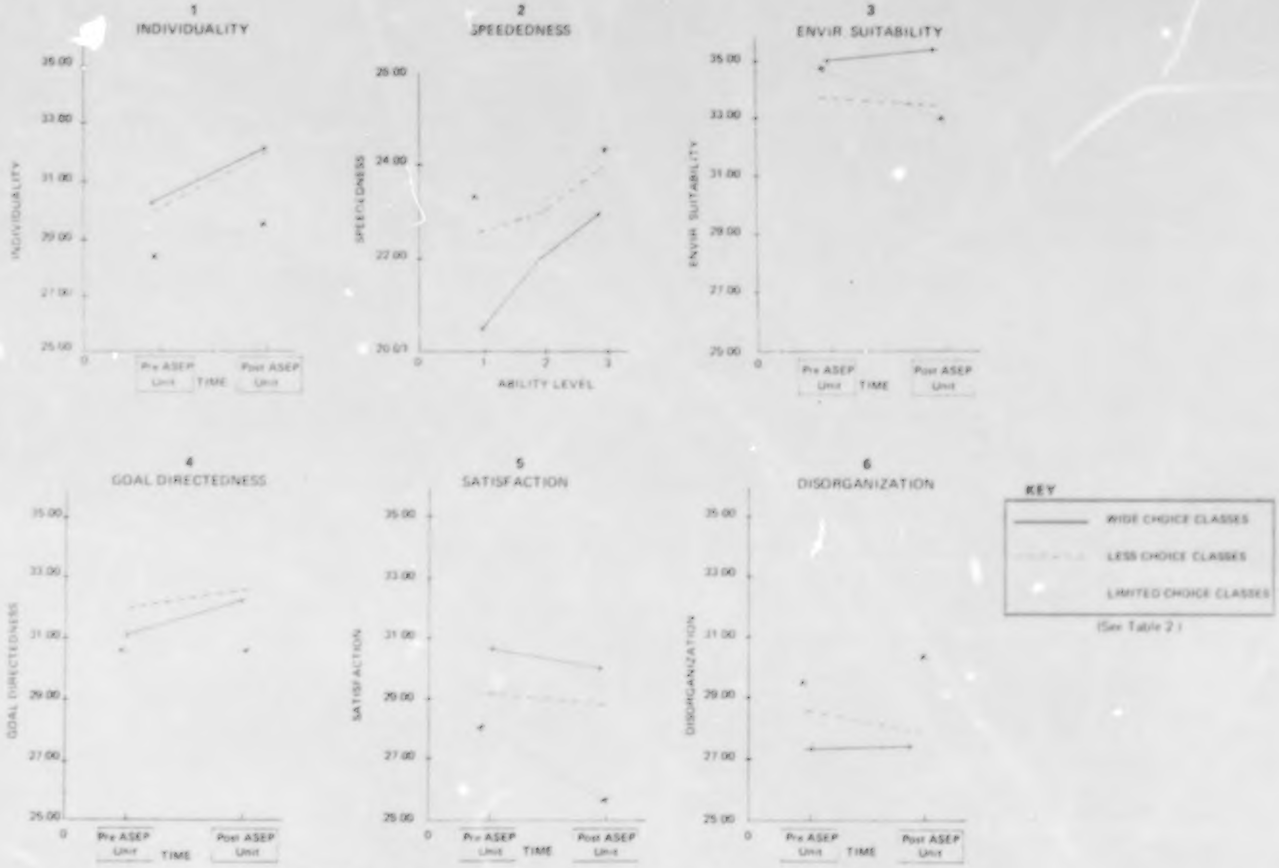


FIGURE 3. Graphical representation of results summarized in Table 2

References

ANDERSON, G.J. *The assessment of learning environments: A manual for the Learning Environment Inventory and the My Class Inventory.* Atlantic Institute of Education, Halifax, 1971.

ANDERSON, G.J. & WALBERG, H.J. "Learning environments", Chapter 6 in Walberg, H.J. (Ed.), *Evaluating educational performance.* McCutchen, Berkeley, 1974.

ASEP. *A guide to ASEP.* Victorian Government Printer, 1974.

FRASER, B.J. "The impact of ASEP on pupil learning and classroom climate", *Research in Science Education,* **5**: 1-12, 1975.

GETZELS, J.W. & THELEN, H.A. "The classroom as a unique social system", in N.B. Henry (Ed.), *National society for the study of education yearbook.* University of Chicago Press, Chicago, 1960.

OWEN, J.M. "A review of current and planned research concerning the Australian Science Education Project." *Research in Science Education,* **5**: 33-42, 1975.

RANDHAWA, B.S. & FU, L.L.W. "Assessment and effect of some classroom environment variables." *Review of Educational Research,* **43**(*3*): 303-321, 1973.

TISHER, R.P. & POWER, C.N. "The effects of classroom activities, pupils perceptions and educational values in lessons where self-paced curricula are used." *Research Report,* Monash University, 1975.

WALBERG, H.J. "Models for optimizing and individualizing school learning." *Interchange,* **2**(*3*): 15-27, 1971.

WALBERG, H.J. & AHLGREN, A. "Predictors of the Social Environment of Learning." *American Educational Research Journal,* **7**(*2*): 153-167, 1970.

WINER, B.J. *Statistical Principles in Experimental Design.* 2nd Edition, McGraw Hill, New York, 1971

ZOLLER, U. & WATSON, F.G. "Teacher training for the 'second generation' of science curricula: The curriculum proof teacher." *Science Education,* **58**(*1*): 93-103, 1974.

THE EFFECT OF SCIENCE COURSES ON PERCEPTION OF SCIENTISTS AND SELF

Richard T. White and Lindsay D. Mackay

We teach science to bring about certain changes in students. It seems reasonable to expect that among these changes will be an increase in the students' knowledge of the attributes that distinguish scientists: the more they study science the more they should be aware of what are desirable habits or attitudes for scientists to have. We might also expect that as a result of studying science, students will come to accept the attributes of scientists as desirable models for themselves to adopt, and will come to see descriptions of scientists' attributes as applicable to themselves. In this paper we report the effects of senior secondary and tertiary courses in Victoria on both objectives. It will be seen that there is some cause for disquiet.

Knowledge of the attributes that are desirable in scientists, and perception of one's own possession of these attributes, may be measured by the Tests of Perception of Scientists and Self (Mackay and White, 1974, 1976). The two forms of the tests, *TOPOSS – Scientists* and *TOPOSS – Self*, were administered to random samples of one-tenth of the students in forms 4 and 6 of seventeen high schools randomly selected from those in the Melbourne metropolitan area. No student answered both tests. In addition to the test, form 4 students were asked which subjects they intended to study in the next year, when there would be much greater choice open to them than there had been in their schooling to that time, and form 6 students were asked which subjects they were studying. This enabled us to divide the form 4 and 6 students into two groups, those who chose to study a science subject and those who did not. In the main the students followed what still seems to be a typical pattern in Victoria, that generally they chose to study several science subjects or none.

On seeing the results for the forms 4 and 6 students, we decided to add a third group, of trainee teachers attending Monash University Education Faculty and Rusden State College. We divided them into science and non-science groups on the basis of their teaching methods subjects.

Mean scores on the tests for the various subject choice and academic level groups are given in Table 1, with the related analyses of variance in Table 2.

The *TOPOSS – Scientists* scores show a moderate level of perception of desirable attributes of scientists. The TOPOSS tests consist of twenty pairs of statements, either about scientists (*TOPOSS – Scientists*) or about the respondent (*TOPOSS – Self*). In each pair, the statements have been shown to be equally socially acceptable to senior secondary school students, but to differ in their applicability to scientists. The respondent must choose one of each pair, therefore someone with no perception at all of what scientists should be like can be expected to score about 10. In that light, a mean of 16 out of 20 shows some general perception of what scientists should be like, but in our judgment not a particularly high one.

The means for the various groups and the ANOVA table for *TOPOSS – Scientists* show that there is little difference between the groups. There is remarkably little change from form 4 to trainee teachers, either for the total sample or for those who choose to study science and those who do not. It must be remembered, too, that the trainee teachers are a more select group than the fourth-formers, and could be expected to score more highly because of greater verbal skills, intelligence, and general world-wiseness. They do not do much better. It seems

TABLE 1

Mean Scores for TOPOSS – Scientists and TOPOSS – Self

	Choose Science					
	Yes			No		
	Form 4	Form 6	Teachers	Form 4	Form 6	Teachers
	TOPOSS – Scientists					
Mean	16.2	16.8	16.9	16.4	15.9	16.8
n	24	16	32	11	11	19
	TOPOSS – Self					
Mean	11.6	9.6	11.3	10.4	11.8	9.7
n	25	15	32	8	12	20

TABLE 2

Analysis of Variance of TOPOSS Scores

Source	TOPOSS – Scientists			TOPOSS – Self		
	df	MS	F	df	MS	F
Academic level	2	3.5	.4	2	1.5	.2
Subject choice	1	1.9	.2	1	.9	.1
Interaction	2	2.5	.3	2	34.0	4.2*
Within cell	107	9.0		106	8.2	

* $p < .025$

that neither upper secondary and tertiary science courses nor cultural influences are doing anything to improve students' perceptions of desirable attributes of scientists.

A mean of about 10 is to be expected for the *TOPOSS – Self* test when it is applied to a group that is not specially selected for its association with science, since the respondent has to choose one statement from each of twenty pairs with regard to its applicability to himself when in each pair the statements are known to be equally socially acceptable. For all the groups in this investigation the *TOPOSS – Self* means are around 10. They show little overall change from form 4 to form 6 and the trainee teachers, but there is the remarkable and unfortunate result that those who study science in forms 5 and 6 come to have self-perceptions less like scientists, while those who do not study science in these years become more like scientists. From the ANOVA table for *TOPOSS – Self* the mean square within cells is 8.2, therefore the standard deviation of scores in the groups can be estimated as 2.9. The study of science for two years appears to lead to a change in self-perception of about two-thirds of a standard deviation away from congruence with scientists. If it were found that two years of schooling led to a drop in IQ of 10 points there would be a public outcry. Readers who believe that science courses should bring students to be more like scientists in their self-perceptions should be just as concerned about this result.

There is not much consolation to be found in the results for trainee teachers, either. Although the form 4 to form 6 trend is reversed, the trainee teachers are no better than the form 4 students, and in any case the improvement from form 6 might be due solely to the process of selection and dropout rather than an effect of the courses the trainee teachers have studied.

The *TOPOSS – Self* scores give teachers of non-science subjects no grounds for complacency either: those who did not study science in the last two years of secondary school became more like scientists. This effect seems easiest to interpret as a general rejection of the model upper secondary students have held before them. A longitudinal study is really necessary to check the opposite result for the trainee teachers. It would also be interesting to see whether a similar pattern of results would be obtained in other states, or perhaps more pertinently under other social conditions such as in Australia in later years or in other countries now.

References

MACKAY, L.D., & WHITE, R.T. "Development of an alternative to Likert scaling: Tests of perception of scientists and self (TOPOSS)", in R.D. Linke and L.H.T. West (Eds.), *Research in Science Education*, 4, Melbourne, Australian Science Education Research Association, 1974.

MACKAY, L.D., & WHITE, R.T. *Tests of perception of scientists and self.* ACER, Melbourne, 1976 (in press).

NON-LINEAR RELATIONSHIPS BETWEEN MEASURES OF CLASSROOM ENVIRONMENTS AND OUTCOMES

Colin Power and Royce Sadler

Introduction

During the 1960's many researchers attempted to classify classroom phenomena and to relate measures of teacher-pupil interaction to measures of pupil cognitive and affective outcomes. It was hoped that the research would yield a set of key behaviours essential for effective teaching. For the most part, research workers simply checked for the existence of linear relationships between measures of teacher behaviour on the one hand and class achievement gains on the other. Unfortunately the bulk of these studies suffer from serious methodological and conceptual weaknesses (Rosenshine, 1971; Dunkin & Biddle, 1974) leading reviewers to lament:

> the research on teaching in natural settings to date has tended to be chaotic, unorganized and self-serving.

Not surprisingly, the research has not been successful in unequivocally establishing a set of key teacher competencies. The weaknesses of the research and the inconsistencies in the results have led critics of classroom research (e.g. Heath & Nielson, 1974) to view the research as useless to advocate its demise. Meanwhile many researchers who believed in the myth of universally effective teacher behaviours have now moved from classroom research to the development of minicourses and modules designed to develop what they believe to be key teaching competencies. In many respects one can draw a parallel between classroom research and the attempts of the alchemists to find the philosopher's stone capable of turning lead into gold.

The failure to find a philosopher's stone in education is hardly grounds to abandoning systematic attempts to unravel the mysteries of teaching. There are sound logical and practical reasons for continuing with classroom research, just as there were sound reasons for continuing to study chemical phenomena. After all, whatever effects schools, curricula and teachers can and do have on students derive basically from the interactions between students, teachers and materials in classroom settings. Just as progress in chemistry and chemical technology is dependent on the systematic study of interactions occurring in different chemical systems, so too progress in educational theory and practice may depend more on the work of those attempting to understand classroom processes than on the efforts of educational alchemists.

Attempting to understand the complexities and realities of classroom systems undoubtedly demands sophisticated conceptual frameworks, ingenious methodologies and sensitive observers. There are signs of a growing maturity among those few research workers who are still active in the field. Recent research studies have been able to avoid many of the pitfalls which plagued early search, have initiated many significant methodological advances and explored new paradigms for research (Brophy & Everton, 1974; Good & Grouws, 1975; Tisher & Power, 1975; Power, 1976). Furthermore, from the research, new theoretical frameworks based on more carefully documented assumptions are beginning to emerge (Good & Power, 1976; Lundgren, 1972). This research and theory tends to confirm the view that relationships between classroom processes and outcomes are complex. For instance, many of the relationships between teaching behaviours and outcomes turn out to be non-linear, rather than linear.

To cite but one example, Brophy & Evertson (1974), Soar (1969) and Nuthall (1974) found that pupil gains increase as teacher indirectness (use of pupil ideas, student talk) increases, but only up to a point. Beyond that point, less growth occurs. Further the point at which maximum growth occurs appears to be a function of the complexity of the learning task and the nature of the learning context. Specifically, the more abstract the task, and the higher the socio-economic level of the school, the higher the level of indirectness which is optimal. For concrete tasks and low socio-economic contexts, more teacher directness proved optimal.

In two of the most detailed and comprehensive process-product research programs to date, Soar & Soar (1973) and Bropjy & Evertson (1974) have found that *most* teacher behaviours were non-linearly rather than linearly related to student achievement and satisfaction. In particular, many teaching behaviours show an "inverted V" relationship to learning, indicating that the ideal is somewhere between the extremes. Both research teams argue that the possibility of non-linear relationships between process and product measures should be investigated routinely and that these relationships be checked out in different types of learning contexts. Failure to check for non-linear relationships and failure to take seriously the importance of contextual variables has been two reasons why previous process-product research has failed to yield impressive results (Good, Biddle & Brophy, 1975). In addition, recent theories of teaching also lead one to anticipate that variables and outcomes will be non-linear and that success in a given context (whole class, group, individualised) for a given type of pupil is contingent on the orchestration of optimal levels of several process variables simultaneously (Good & Power, 1976).

Recently Brown (1975) accused educational researchers of over-using and abusing the linear model in educational research. He claimed that many qualitative educational researchers have a very limited view of educational reality and a tendency to remain distant from their data. He argued that researchers need to explore the potential of non-linear and non-additive relations among variables, along with other types of models (e.g. optimization models, projective models).

The purposes of this study were to explore a series of non-linear models linking measures of classroom processes (observed behaviour, student perceptions) with instructional outcomes in a context of particular interest to science educators, viz classes using Australian Science Education Project Materials. The study forms part of a larger project (Tisher & Power, 1973; 1975).

Method

Initially, a *Teacher Opinion's Scale* (ASEP, 1973) and a *Teaching Practice Questionnaire* (Adams, 1970) were administered to a sample of 42 science teachers, 79 postgraduate science education majors and 16 ASEP staff members. The data from these questionnaires were analysed using a principal components procedure to establish value dimensions and the results were used to establish clusters of individuals. Each cluster contained teachers whose value orientation towards teaching and science curricula were similar. The 20 teachers asked to use the core of the ASEP unit *How Many People?* were selected so that several representations of each cluster were included in the study. Thus, some teachers whose values were congruent with those of ASEP and others whose values were dissonant were included in the sample.

Two of the five lessons required to complete the core of the unit were videotaped, and the videotapes were analyzed using a multi-faceted coding scheme (SABIC) designed especially for studying individualised learning contexts. Achievement and attitude pre and post tests, related directly to the cognitive and affective objectives of the unit being used, were administered in the first and seventh lesson. In addition, the *Class Activities Questionnaire* (Steel, House and Kerins, 1971) and the *Learning Environment Inventory* (Anderson, 1971) were administered in order to determine student perceptions of the learning environment.

Linear and non-linear regression analyses were undertaken in an attempt to explore relationships among student pre-test measures of student perceptions and outcomes using the pupil as the unit of analysis (N = 315). Using the class mean as the unit of analysis (N = 20), linear and non-linear regression analyses linking all antecedent, process and product measures were conducted.

Results

Pupil as the unit of analysis. What contribution does a knowledge of how an individual perceives his learning environment make to explaining the variance in instructional outcomes, over and above that accounted for in terms of his entry characteristics? In order to answer this question, first a series of linear models of the following form were set up

$$Y = a + b_1X_1 + b_2X_2 \tag{1}$$

where Y = achievement or attitude post-test for unit *How many people*

X_1 = ability (IQ measured by Inter D test of scholastic aptitude)

X_2 = score on a LEI or CAQ scale.

By including a product term of the type $X_1 X_2$ in the equation

$$Y = a + b_1X_1 + b_2X_2 + b_3X_1X_2 \tag{2}$$

one can check to see whether X_1 and X_2 interact, that is, the effects of an environmental condition X_2 depend on the ability of the student. By including an X_2^2 term as well, one check for the possibility of accelerations or decelerations of environmental effect:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_1X_2 + b_4X_2^2 \tag{3}$$

Computationally the task is relatively easy — one merely needs to create new variables by transforming original measures. This can be accomplished readily by most standard computer packages (e.g. SPSS).

Tables 1 and 2 show the results of these analyses. In no case was the amount of variance accounted for particularly high. The addition of non-linear terms did improve predictability significantly in a number of instances, but in each case the magnitude of the increment was small and its educational significance therefore meagre.

TABLE 1

Nonlinear regression analysis: Perception Scales vs Achievement (N = 315 pupils)

Pupil Perceptions	Increment in variance				Total R^2
	Linear		Interaction	Non-linear	
	IQ	ENV.	IQxENV	ENV.	
Cohesiveness	247**	003	001	009*	260**
Diversity	247**	000	005	000	252**
Formality	247**	003	000	000	250**
Speed 247**	247**	000	001	001	249**
Environment	247**	003	000	011*	261**
Friction	247**	002	001	000	250**
Goal direction	247**	008	005	005	265**
Favouritism	247**	024**	000	005	276**
Cliqueness	247**	001	000	001	249**
Satisfaction	247**	008	002	003	260**
Disorganisation	247**	019**	002	006	274**
Difficulty	247**	002	000	001	250**
Apathy	247**	024**	001	001	273**
Democratic	247**	001	015*	000	263**
Competitive	247**	003	010*	004	264**
Independent inquiry	247**	004	000	000	251**
Indifference	247**	024**	001	001	273**
Humour	247**	015*	011*	002	275**
Cramming	247**	002	000	000	249**
Interpretation	247**	001	027**	004	279**
Participation	247**	024**	013*	022**	306**
Translation	247**	012*	031**	006	296**
Inform.process	247**	011*	001	015*	274**
Involvement	247**	006	012*	000	265**
Interaction	247**	016**	011*	002	276**
Concern	247*	003	010*	014*	274**

* $p < 0.05$ ** $p < 0.01$

TABLE 2

Non-linear regression analyses: Perception scales vs attitudes (N = 315)

Pupil Perceptions	Increment in variance				Total R^2
	Linear		Interaction	Non-linear	
	IQ	ENV.	IQxENV	ENV.	
Cohesiveness	042**	083**	001	000	126**
Diversity	042**	015*	013	000	070**
Formality	-42**	008	008	004	062**
Speed	042**	010*	000	006	058**
Environment	042**	016**	000	000	058**
Friction	042**	013*	002	001	058**
Goal direction	042**	053**	000	000	095**
Favouritism	042**	026**	002	003	073**
Cliqueness	042**	000	004	003	049**
Satisfaction	042**	050**	005	000	097**
Disorganization	042**	037**	000	002	081**
Difficulty	042**	000	007	000	049**
Apathy	042**	052**	004	000	098**
Democratic	042**	003	002	005	052**
Competitive	042**	000	002	020**	064**
Ind.Inquiry	042**	015*	001	016*	074**
Indifference	042**	033**	002	015*	092**
Humour	042**	000	003	000	045**
Cramming	042*	004	008	002	056**
Interpretation	042**	003	000	013*	058**
Participation	042**	039**	005	006	092**
Translation	042**	022*	011*	001	076**
Inform.Process	042**	012*	002	004	060**
Involvement	042**	011*	001	001	055**
Initiation	042**	003	003	001	049**
Concern	042**	025**	011*	009*	087**

* $p < 0.05$ ** $p < 0.01$

In order to interpret relationships, contour regression surfaces similar to those shown in Figures 1 and 2 were plotted. In these figures the numerals on the contour lines indicate predicted achievement, in SD units, and the axis refer to ability and environment measures. In Figure 1 the environment axes refers to the environment measure on the LEI, i.e. the measure which indicates the extent to which pupils perceive materials and equipment as readily available and take a pride in their classroom. Figure 1 indicates that individual achievement is lowest when low ability pupils rate the environment as "intermediate" and is maximised for all pupils when the environment is perceived as either very enriched or very poor!

Figure 2 indicates that a heavy emphasis on interpretation and beyond information given, facilitates the achievement of low ability students but inhibits that of high ability students, while middle ability students are largely unaffected. Where students indicate that the teacher is very concerned and interested in them as individuals, students of all ability levels perform moderately well, but high ability students performed best when they felt the teacher was not particularly friendly towards them as a person. High overall levels of class participation in ASEP lessons seems to be particularly important for low ability students, but to inhibit the achievement of high ability students. Middle ability students performed best when class participation was either very high or very low. However, an interesting reversal is apparent when one examines the data for individual (as opposed to class) involvement and initiation levels as measured by the extent to which pupils say they are frequently asked and ask questions in class. Low ability pupils performed better when their reported levels of involvement and initiation were low, high ability students when involvement was high, while middle ability students were not affected greatly.

Class as unit of analysis. A second series of analyses were designed to test whether the addition of squared terms in the regression model produced significant increments in the explained variance of class outcomes measures. The regression equation had the form

$$Y = a + b_1X_1 + b_2X_1^2 + b_3X_2 + b_4X_2^2$$

where Y = predicted achievement post-test score.

X_1Y_1 = behaviour measure (SABIC)

X_2Y_2 = perception measure (LEI)

This model was tested against one which had the form

$$Y = a + b_1X_1 + b_2X_2$$

to determine whether the additional terms produced a significant increment in the explained variance. The results for two behaviour measures and a number of the LEI scales are reported in Table 3.

Significant increments to the explained variance in achievement were obtained when squared terms were added, based on teacher-class interaction and the perception measures apathy, democratic and competitiveness. Also a significant increment was obtained when the additional squared terms were derived from the SABIC measure on teacher-pupil interaction and the LEI scale democratic. The respective regression equations were:

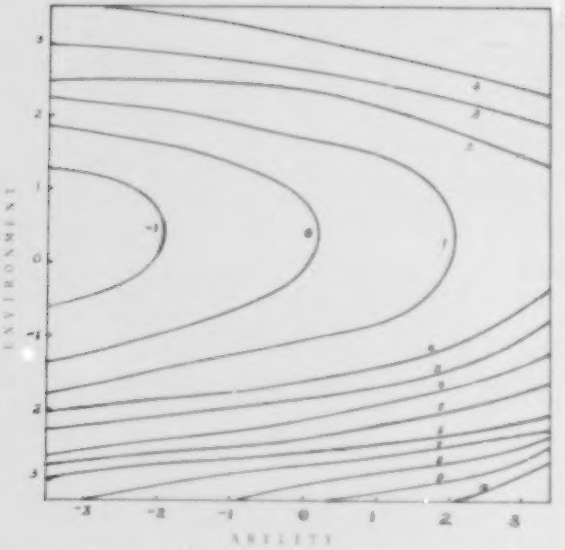


FIGURE 1. Non-linear regression surface (model with product terms): Environment versus ability (achievement as criterion).

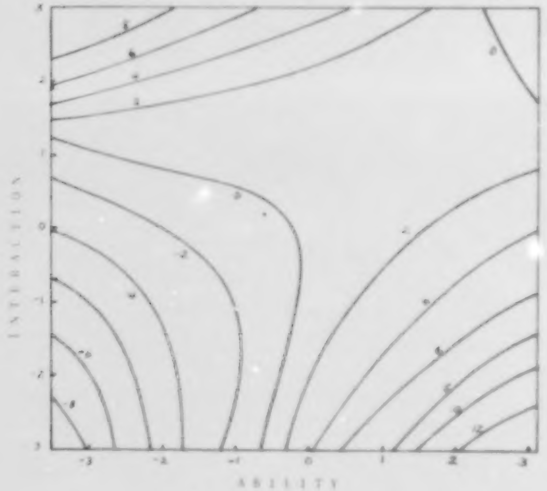


FIGURE 2. Non-linear regression surface (model with product terms): Interpretation versus ability (achievement as criterion).

TABLE 3

Regression models: Squared terms included selected behaviour and perception measures and achievement

Behaviour Measure	Perception Measure	Proportion of Criterion Variance Explained		
		I	II	III
T – C interaction	Cohesiveness	27	29	12
	Speed	27	27	14
	Friction	27	27	14
	Apathy(1)	27	51	16*
	Democratic(2)	27	27	20*
	Competitiveness(3)	27	56	17*
T – P interaction	Cohesiveness	42	42	10
	Speed	42	48	09
	Friction	42	42	11
	Apathy	42	54	07
	Democratic(4)	42	42	15*
	Competitiveness	42	56	11

Notes:
I Variance accounted for by the behaviour measure alone (linear model)
II Variance accounted for by the behaviour and perception measure (linear model)
III Increment due to the square terms for behaviours and perceptions..
* $p < 0.05$ if increment significant

Note, that the pre-test measure and/or ability measure were not included in the equations. These measures account for most of variance when included and in these explorations it was intended to seek out relationships between the behaviour and perception measures with the criterion. The various full regression models accounted for 31 to 73 per cent of the variance in achievement.*

Footnote: The regression analyses were based on measures derived from class means. As there were only 20 classes, the findings for these analyses (where four predictors are introduced into the regression model) must be treated with some caution.

$$(1) \quad Y = 0.20X_1 - 0.01X_1{}^2 + 2.15X_2 - 0.09X_2{}^2 + 5.12$$

$$(2) \quad Y = 0.13X_1 - 0.01X_1{}^2 + 13.78X_2 - 0.48X_2{}^2 - 80.68$$

$$(3) \quad Y = 0.04X_1 - 0.01X_1{}^2 + 30.58X_2 - 0.93X_2{}^2 - 231.17$$

$$(4) \quad Y = 0.66X_1 - 0.01X_1{}^2 + 11.72X_2 - 0.41X_2{}^2 - 74.32$$

The next step was to plot the regression surfaces generated by the preceding equations. As they each had the same sign for the corresponding coefficients it was decided to reproduce only one surface here. At the time of writing, other computations are proceeding with other combinations of behaviour and perception measures. Figure 3 shows the regression surface for the first regression equation above, where the behaviour measure is Teacher-Class interaction and the LEI measure is apathy. The resulting surface looks somewhat like an aeroplane hangar set on a curved and sloping base. The regression surfaces for the other equations will be somewhat similar to that in Figure 3.

Figure 3 shows that for a given level of teacher-class interaction there is a level of apathy beyond which the achievement of the class decreases markedly. So, the less pupils care about what the class does and the lower their concern for the success of the class (provided that this "apathy" is greater than the specific optimum value), the lower will be the class achievement. For low levels, small increments in apathy are associated with increments in class achievement. When apathy is high, increases in teacher domination and control (i.e. increases in teacher-class interaction) only raise the achievement of the class by small amounts. Presumably in these situations pupils resent the domination by the teacher and do not respond with greater effort in the learning tasks.

Concluding comments

The results of the non-linear analyses reported in this paper are disappointing. In most instances, the addition of non-linear terms added nothing to the model and in those cases where the increment in the variance accounted for was significant, the educational significance of the finding is open to question.

Coupled with the non-linear explorations undertaken in the first ASEP project undertaken by Tisher and Power (1973), the results indicate that one cannot even assume that the strategies which are effective in one unit will work in the next. In the unit *How Many People?*, it would seem that frequent teacher contacts with individual pupils facilitates achievement, but that the reverse is true in the unit *Light Forms Images*. Is this another case supporting Rosenshine's claims that the research is chaotic? Why are there so few strong relationships and why do many of those which appear strong turn out to be conflicting?

The evidence suggests that with the exception of managerial efficiency in the sense that the teacher ensures students devote the bulk of their time on the learning task, no particular strategy or teacher quality is universally effective for all students, in all ASEP units or for all goals. Indeed if the contextually-based theory of Good and Power (1976) has any substance, we must expect that any strategy chosen by the teacher will be facilitative for some students in some circumstances but at the same time prove disfunctional for others. For instance, one explanation for the apparent reversal of the relationship between teacher-pupil interaction and

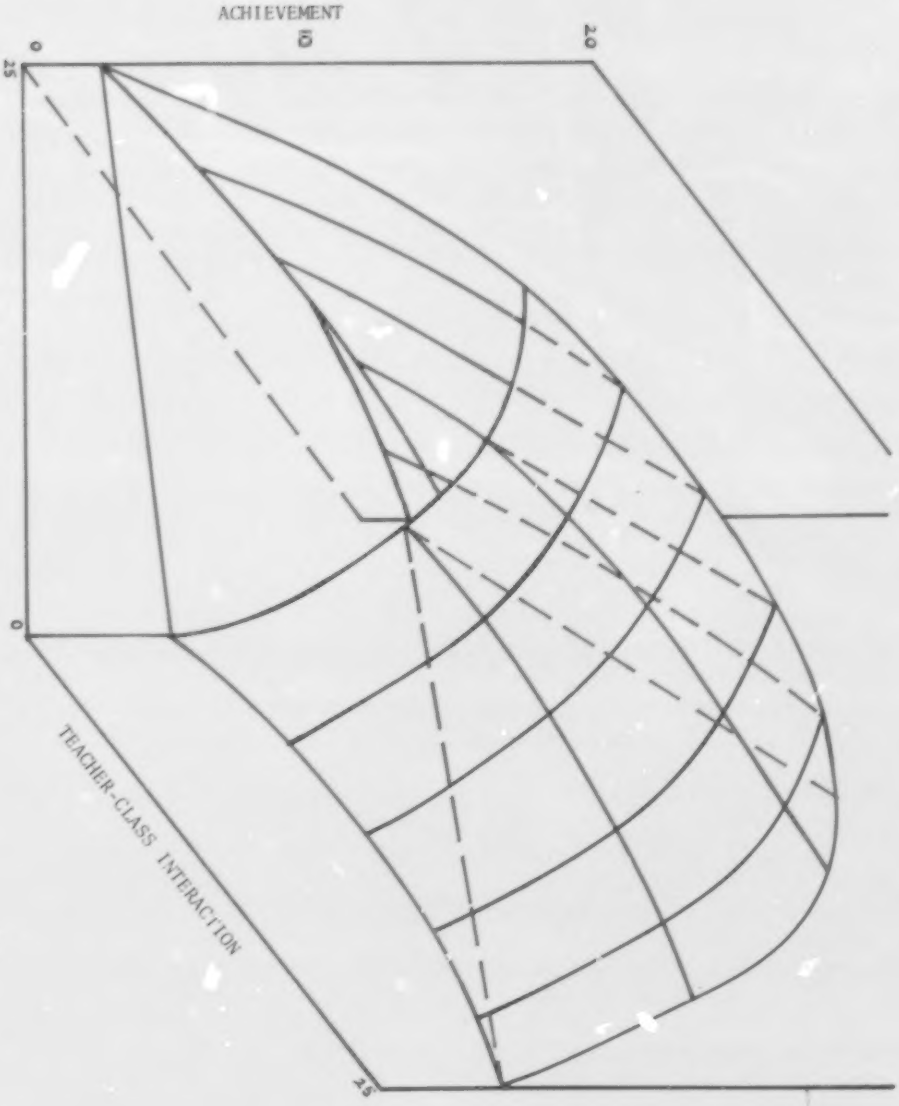

ACHIEVEMENT
0
10
20
25
APATHY
0
TEACHER-CLASS INTERACTION
25

FIGURE 3: Regression surface for non-linear model.

achievement lies in the nature of the learning contexts. In the unit *Light Forms Images* students work individually at experiments designed to help students understand basic ideas about lenses. The unit is highly structured and the goals convergent and cognitive. Under these circumstances, a strategy favouring convergence (working with groups and occasionally the whole class, rather than individuals) may be appropriate. On the other hand, *How Many People?* is a controversial unit about the problems of over population. Unit goals are divergent and largely affective. Under these circumstances, a strategy fostering divergence (group discussion, working with individuals rather than whole class) may be appropriate.

In other words, a prescriptive theory of teaching which enables us to predict the effects of a given strategy is impossible, as is the hope that one can isolate a set of key behaviours which will always work irrespective of the context, type of pupil or goal. CTBE programs which are designed to do more than to stamp "key" behaviours into prospective science teachers, do seem to be built on a shaky, if not dangerous, set of assumptions.

Given the complexities of classrooms and contexts in which they are set, what can the research worker do? First, as one of the authors has argued elsewhere (Power, 1976), one can attempt to utilize the strengths of alternative paradigms for research. Whereas multivariate techniques can be very useful in exploring empirical relations among environmental and outcome conditions, ethnographic approaches can help us understand the classroom from the perspective of the participants. Case studies of classes lying well outside the regression curves described in this paper, using ethnographic methodologies, would be particularly useful. Second, a less prescriptive and authoritative view of research needs to be taken. Educational research should aim to increase the problem solving capacity of the educational system by sensitizing teachers and administrators to the realities of classrooms, clarification of problems and encouraging debate. It cannot and should not seek to provide final answers to questions or objective evidence to settle controversies.

References

ADAMS, R. "Perceived teaching styles." *Comparative Education Review*, **14**: 50-59, 1970.

ANDERSON, G. *The Assessment of Learning Environments: A Manual for the Learning Environment Inventory and the My Class Inventory*. Atlantic Institute of Education, Halifax, Nova Scotia, 1971.

A.S.E.P. *A Guide to A.S.E.P. The A.S.E.P. Handbook*. The A.S.E.P. Teacher-Education Materials, Australian Science Education Project, 1973.

BROPHY, J. & EVERTSON, C.M. *The Texas Teacher Effectiveness Project*. Presentation of non-linear relationships and summary discussion. Report No. 74-6 University of Texas at Austin, 1974.

BROWN, D. "Down with the linear model." *American Educational Research Journal*, **12**: 491-505, 1975.

DUNKIN, M. & BIDDLE, B. *The Study of Teaching*, Holt, Rinehart and Winston, New York, 1974.

GOOD, T.L., BIDDLE, B.J. & BROPHY, J.E. *Teachers make a Difference*. Holt, Rinehart & Winston, New York, 1975.

GOOD, T.L. & GROUWS, D.A. *Process-product relationship in Fourth Grade Mathematics Classrooms*. Final report of National Institute of Education Grant NEG-00-3-0123, 1975.

GOOD, T.L. & POWER, C.N. "Designing successful classroom environments: Toward a contextual theory of teaching." *Journal of Curriculum Studies*, **8**(*1*): 1-16, 1976.

HEATH, R. & NIELSON, M. "The research for performance-based teacher education." *Review of Educational Research*, **44**: 463-484, 1974.

LUNDGREN, U. *Frame factors and the teaching process*, Almqvist & Wiksell, Stockholm 1972.

NUTHALL, G. "Is classroom interaction research worth the effort involved?" *New Zealand Journal of Educational Studies*, **9**(*1*), 1974.

POWER, C.N. "Competing paradigms in science education research." *Journal of Research in Science Teaching*, **13**(*5*): 1-9, 1976.

ROSENSHINE, B. & FURST, N. "Research on teacher performance criteria", in Smith, B.O. (Ed.) *Research in Teacher Education*. Prentice Hall, Englewood Cliffs, 1971.

SOAR, R.S. "Optimum teacher-pupil interaction for pupil growth." *Classroom Interaction Newsletter*, **5**(*1*): 38-45, 1969.

SOAR, R.S. & SOAR, K.M. *Classroom behaviour, pupil characteristics and pupil growth for the schoolyear and the summer*. University of Florida, NIE Grant, 1973.

STEELE, J., HOUSE, E. & KERINS, T. "An instrument for assessing instructional climate through low-interference student judgements." *American Educational Research Journal*, **7**: 447-466, 1971.

TISHER, R.P. & POWER, C.N. *The effects of teaching strategies in mini-teaching and micro-teaching situations where Australian science education project materials are used.* Mimeographed report, Faculty of Education, The University of Queensland, 1973.

TISHER, R.P. & POWER, C.N. *The effects of classroom activities, pupils' perceptions, and educational values in lessons where self-paced curriculum materials are used.* AARCDE Report, Monash University, 1975.

AN EXAMINATION OF RELATIONSHIPS BETWEEN COGNITIVE PREFERENCES, FIELD-INDEPENDENCE AND LEVEL OF INTELLECTUAL DEVELOPMENT

Anthony J.D. Blake

Introduction

Efforts to account for individual differences in approach to and performance on cognitive tasks have led to the development of a number of constructs which may be subsumed by the generic label, "cognitive style". Much of the work in science education has centred around investigations of what Heath (1964) first described as *cognitive preferences.* In summarising what is known of cognitive preferences, MacKay (1975) has indicated that they are related to performance on cognitive tasks and that they should reflect features of the cognitive structure of the learner.

A second cognitive style characteristic which is of interest to science education is the cognitive-perceptual characteristic which Witkin and his colleagues have termed *field-independence* (Witkin et al., 1962). This characteristic is of special interest because Pascual-Leone has incorporated it as a factor in his neo-Piagetian model of intellectual functioning (Pascual-Leone, 1969; Pascual-Leone and Smith, 1969). In order to understand the hypotherized relationship between field-independence and performance on cognitive tasks, it is necessary to amplify the Pascual-Leone model. The following summary is based on the description given by Case (1974).

1. The basic construct of Pascual-Leone's theory is the Piagetian *scheme.* Schemes are conceptualized as mental blueprints which represent experience and produce behaviour.
2. New schemes are assumed to be acquired by:
    - (a) the modification of an old scheme;
    - (b) the combination and consolidation of several old schemes.
3. Problem-solving involves a systematic activation of various forms of schemes.
4. Unless its releasing component is activated by the immediate perceptual input, the activation or rehearsal of any scheme requires the application of "mental effort". Since the amount of mental effort which can be applied at any particular time is limited, the number of schemes which can be activated in any one mental step also is limited.
5. If two schemes are activated which have incompatible content, cognitive conflict ensues, or "disequilibrium" in the Piagetian sense.
6. Whether or not an individual actually solves a particular problem is held to depend on the following four factors:
    - (a) the size and quality of the repertoire of schemes which the subject brings to the problem;
    - (b) the maximum number of schemes which the subject's system is capable of activating at any one time – this maximum mental effort or M-power is assumed to vary both within and across age groups;
    - (c) the subject's tendency to *utilize* the full M-power which he has available (this assumes that some subjects are habitually low M-processors – that is, they

prefer to look at or to respond to problems in the simplest manner possible (with a set of operations involving the least mental effort));

(d) the relative weight which the subject gives to cues from the perceptual field, as opposed to cues from other sources, in selected schemes.

From the point of view of this study, the most critical feature of Pascual-Leone's theory is as follows. The individual differences described in 6(c) and (d) above are assumed to be highly correlated and together are posited to account for the dimension of cognitive style called "field dependence-independence". Case (1974, p. 5) described the relationship in the following way:

> Field-dependent subjects are assumed to be habitually low M-processors who assign higher weight to perceptual cues than to cues provided by the task instructions, in situations where these two sets of cues suggest conflicting executive schemes. Field independent subjects are assumed to be habitually high M-processors, who assign a higher weight to the task instructions than to perceptual cues in such conflicting situations.

In essence, then field-independent subjects are less prone to be distracted or fazed by irrelevant perceptual "noise" when they attend to a problem and proceed to attempt to solve it, than are field-dependent subjects. This role of field dependence-independence in affecting performance in cognitive tasks is supported by results obtained by Pascual-Leone (1969), Case and Globerson (1974), Niemark (1975), and, to a lesser extent by Saarni (1973). These studies indicate that field-independence is associated with superior performance on cognitive tasks. In fact, Karplus has offered the influence of this cognitive style characteristic as a possible explanation for the generally poor performance of subjects on the Karplus Ratio Puzzle (Karplus et al., 1974). In so doing, Karplus and his colleagues referred to cognitive style as a "personal preference", a description which bears a striking resemblance to the concept of cognitive preference.

In summary, one line of investigation has identified the construct, cognitive preference, as related to cognitive performance. Another line of investigation has described the construct, field-independence, as a factor involved in cognitive performance. One may therefore ask two questions. Firstly, what relationship exists between there two cognitive style characteristics? Secondly, how do they both relate to level of intellectual development? Flavell has described the Piagetian notion of formal thought as

> "a generalized orientation . . . towards problem solving: an orientation towards organizing data . . . towards isolation and control of variables, towards the hypothetical, and towards logical justification and proof." (Flavell, 1963, p.211).

One might expect, therefore, that the degree of field-independence and the cognitive preferences of formal-operational thinkers would be different from subjects of the same age, but who are concrete-operational.

Purpose

As one facet of a major study of the effect of teaching strategy on intellectual development and cognitive style (Blake, 1976), the following questions were posed:

1. is there a relationship between cognitive preferences and degree of field-independence in

college students?

2. is there a relationship between level of intellectual development and degree of field-independence in college students?
3. is there a relationship between level of intellectual development and cognitive preferences in college students?

Method

The population studied was a group of students entering a course of Primary Teacher Education in a College of Advanced Education. The research design employed for the experimental aspects of the major study (Blake, 1976) limited the number of subjects available to provide data that might answer the questions posed above to fifty-nine. Plainly, such a number is very low for a correlational study. However, the results appear to be worth reporting because they are quite clear-cut.

Over a period of two weeks the subjects were given tests designed to measure level of intellectual development, degree of field-independence and cognitive preferences. The tests employed are described below.

Measure of level of intellectual development. Five Piagetian-type tasks were administered as a battery by individual interview. The tasks employed were:

1. conservation of weight;
2. conservation of displacement volume;
3. separation of variables;
4. exclusion of variables;
5. equilibrium in the balance.

A description of the protocols employed is given by Blake (1976). Subjects were scored separately on each task, their responses being categorized according to the scale on Table 1.

TABLE 1

Scheme for scoring the Piagetian tasks

Level of Performance on Task		Numerical Score
I	pre-operational	1
IIa	early concrete operations	2
IIb	complete concrete operations	3
IIIa	early formal operations	4
IIIb	complete formal operations	5

Task 1 measured to stage IIb, task 2 to stage IIIa, and the other three tasks to stage IIIb. Therefore, the maximum possible total score was 22.

Measure of field-independence. The test employed in this study was the "hidden figures" test;

test Cf-1 from the Kit of Reference Tests for Cognitive Factors (French et al., 1963). Although primarily a test of Thurstone's factor, "flexibility of closure", this version of the test was developed as part of a study of field-independence, and a number of studies have shown that a close relationship exists between these two constructs (Gardner, Jackson and Messick, 1960; Witkin et al., 1962).

Measure of cognitive preferences. The test employed was that described by Mackay (1975) and used in his ETASC study. It yielded scores on the following scales:

Social Sciences	Facts
	Terminology
	Methodology
	Principles and Generalizations
Science	Memory
	Application
	Questioning
	Principles
Mathematics	Verbal
	Graphic
	Symbolic.

Scoring followed the procedure employed by Mackay (Mackay, 1971).

Results and discussion

The matrix of product-moment correlation coefficients between the variables is presented in Table 2. Correlations between the cognitive preferences sub-scales are not included as they are of dubious validity and not pertinent to this study.

Cognitive preferences and degree of field independence. The results strongly support the contention that there is no relationship between these two characteristics of cognitive style, in late adolescents and young adults at least. As field-independence is seen as related to an analytical mode of thought (Witkin, Goodenough and Karp, 1967), one may anticipate a relationship between the more analytic and abstract cognitive preferences and field-independence. The only aspect that lends some support to such an expectation is that the correlation between degree of field-independence and the science questioning cognitive preference approaches statistical significance. It is possible that the correlation would reach significance with a larger population. In general, however, it is clear that no relationship exists between the two cognitive style characteristics.

Field independence and level of intellectual development. No relationship appears to exist between these variables. That is, subjects who displayed formal-operational thinking abilities were not more field-independent than the concrete-operational subjects. It is possible that, with a larger sample from a more heterogeneous population, a demonstrable relationship could be found similar to that described by Pascual-Leone (1969). However, this clear lack of relationship is not in ac[illegible]e Pascual-Leone model.

TABLE 2

Matrix of product-moment correlation coefficients

	Level of intellectual development (total score)	Degree of field-independence
Degree of field-independence	0.032	–
Cognitive Preferences		
Social Sciences		
F	-0.213	0.202
T	-0.038	-0.014
M	-0.080	0.088
P	-0.086	0.160
Science		
M	0.034	-0.151
A	-0.122	-0.001
Q	-0.013	0.248
P	0.096	-0.048
Mathematics		
V	-0.049	-0.146
G	-0.049	0.185
S	0.120	-0.035

$r_{.95}\ (57) = 0.257$

Cognitive preferences and level of intellectual development. Once again the results indicate a complete lack of relationship. In terms of Piaget's conception of formal operational thought (Inhelder and Piaget, 1958) this is surprising, for one might predict that subjects who can operate at a formal level intellectually would be more predisposed to exhibit preferences for abstract modes of presentation or modes which invite or encourage questioning of data and assumptions. It may be, however, that a difference exists between a subject's preference for the mode of presentation of material and his ability to process material presented in different modes. Kempa and Dubé recognised this when they described cognitive preferences as styles which are modes in which the pupil *can* attend to information, as distinct from modes in which the pupil *does* attend (Kempa and Dubé, 1973).

Conclusions and implications

This study suggests that, in late adolescents and young adults, the factors of level of intellectual development, field-independence, and cognitive preferences are unrelated. The following points emerge.

1. The lack of relationship between field-independence, a well established characteristic of cognitive style, and cognitive preferences lends support to Brown's contention that

   > . . . there is no justification for equating differences in expressed cognitive preferences with differences in cognitive style (Brown, 1975)

2. If the hidden figures test is a valid measure of field-independence, then the lack of relationship between degree of field-independence and level of intellectual development is surprising. Success with Piagetian tasks such as separation of variables using flexible metal rods and exclusion of variables using a pendulum appears to involve disembedding relevant factors from a large amount of perceptual background "noise". Hence, one would expect subjects having this success to be more field-independent than those who cannot successfully handle such tasks. The fact that this was not so therefore raises questions about the strategies involved in the performance of such cognitive tasks.
3. Although the results indicate that intellectual maturity in the Piagetian sense is not accompanied by differences in cognitive preferences, such a conclusion is not too meaningful. This is because of uncertainty as to what the existing cognitive preference tests measure. A distinction needs to be made between a preference designated in a situation which does not provoke the subject to process the information intellectually, but asks for an affective response, and a situation in which the subject must process the information intellectually in order to achieve a desired goal. It seems that tests of the sort employed in this study measure the former situation, whereas what is required is a measure of the latter.

References

BLAKE, A.J.D. *Relationships Between Science Instruction Cognitive Style and the Development of Formal Operations in Australian College Students.* Unpublished doctoral thesis, Purdue University, 1976.

BROWN, S.A. "Cognitive preferences in science: Their nature and analysis." *Studies in Science Education,* **2**: 43-65, 1975.

CASE, R. "Structures and strictures: Some functional limitations on the course of cognitive growth." *Cognitive Psychology*, **6**: 544-573, 1974.

CASE, R. & GLOBERSON, T. "Field-independence and central computing space." *Child Development*, **45**: 772-790, 1974.

FLAVELL, J.H. *The Developmental Psychology of Jean Piaget.* Van Nostrand, New York, 1973.

FRENCH, J.W., ECKSTROM, R.B. & PRICE, E.A. *Manual for Kit of Reference Tests for Cognitive Factors.* Educational testing service, Princeton, New Jersey, 1963.

GARDNER, R.W., JACKSON, D.N. & MESSICK, S.J. "Personality organisation in cognitive controls and intellectual abilities." *Psychological Issues,* **2**(*4*), monograph 8, 1960.

HEATH, R.W. "Curriculum, cognition and educational measurement." *Educational and Psychological Measurement,* **24**(*2*): 248-253, 1964.

INHELDER, B. & PIAGET, J. *The Growth of Logical Thinking from Childhood to Adolesence.* Basic Books, New York, 1958.

KARPLUS, E.F., KARPLUS, R. & WOLLMAN, W. "Intellectual development beyond elementary school IV: Ratio, the influence of cognitive style." *School Science and Mathematics*, **74**: 476-482, 1974.

KEMPA, R.F. & DUBÉ, G.E. "Cognitive preference orientation in students of chemistry." *British Journal of Educational Psychology*, **43**: 279-288, 1973.

MACKAY, L.D. *Cognitive Preferences and Achievement in Physics.* Unpublished doctoral thesis, Monash University, 1971.

MACKAY, L.D. *Cognitive Preferences and Achievement in Physics, Chemistry, Science and Mathematics.* Paper presented to the Australian Science Education Research Association Conference, May 1975.

NIEMARK, E.D. Longitudinal development of formal operations. *Genetic Psychology Monographs*, 1975, **91**: 171-225.

PASCUAL-LEONE, J. *Cognitive Development and Cognitive Style: A General Psychological Integration.* Unpublished doctoral thesis, University of Geneva, 1969.

PASCUAL-LEONE, J. & SMITH, J. The encoding and decoding of symbols by children: A new experimental paradigm and a neo-Piagetian model. *Journal of Experimental Child Psychology*, 1969, **8**: 328-355.

SAARNI, C.I. Piagetian operations and field independence as factors in children's problem-solving performance. *Child Development*, 1973, **44**: 338-345.

WITKIN, H.A., DYK, R.B., FATERSON, H.F., GOODENOUGH D.R. & KARP, S.A. *Psychological Differentiation.* New York: Wiley, 1962.

WITKIN, H.A., GOODENOUGH, D.R. & KARP, S.A. Stability of cognitive style from childhood to young adulthood. *Journal of Personality and Social Psychology*, 1967, **7**(*3*), 291-300.

Acknowledgement

The author wishes to express his thanks to Dr L.D. Mackay for permission to use the cognitive preferences test.

LOGICAL CONNECTIVES IN SCIENCE: SOME PRELIMINARY FINDINGS

P.L. Gardner, L. Schafe, U. Myint Thein and R. Watterson

Abstract

Logical connectives are words or phrases which serve as links between sentences, or between propositions within a sentence, or between a proposition and a concept. The Logical Connectives in Science Project has identified about 200 such terms commonly use in school science text material, and has prepared over a thousand test items in order to measure secondary school students' comprehension of these terms. The primary aim of the research is to identify students' specific difficulties; a secondary aim is to explore the relationships between students' ability to comprehend logical connectives and other variables of interest to educational researchers.

The research is still in progress; the present paper reports on recent work in four areas: (1) early findings on pupils' difficulties with logical connectives, based on data obtained from the trial testing of the items; (2) the relationship between logical connective ability (LCA) and socio-economic status (SES); (3) the relationship between LCA and cognitive preferences; and (4) the relationship between LCA and attitudes to a textbook (PSSC Physics) which makes extensive use of a wide range of logical connectives. Significant correlations were found between LCA and SES; however, LCA was found to be uncorrelated with either cognitive preferences or with attitudes to the PSSC text.

> Michael Faraday, one of the world's greatest experimental scientists, was fascinated by the candle. He used it as the basis for a series of talks on the nature of things in 1860. Would you believe that he composed a list of 53 separate observations on a burning candle? Some people would be doing well to get a dozen. Let's begin here. What can you find out about a candle?
>
> K.R. Buckley et al. *Science Makes Sense*
> (Book 1) p.7.

> Mendeleev avoided what would otherwise be additional chemical inconsistencies by boldly leaving gaps in his table, predicting that elements would be discovered to fill the gaps, and describing the properties that the to-be-discovered elements would have. For example, the element after zinc was, in 1871, arsenic. But arsenic does not belong in the same chemical group with aluminum or with silicon. Arsenic is chemically like phosphorus, and therefore belongs in group V. Succeeding elements (selenium, bromine, and so on) also fall into reasonable locations if they follow arsenic located in group V. This means that two elements, one like aluminum and one like silicon, are missing.
>
> A. Turk et al. *Introduction to Chemistry*
> pp. 44-45.

There are some similarities between these two passages of scientific text material: both are about chemistry, and both present historical introductions to their respective topics. But there are also obvious differences. The first is intended for junior high school pupils, the second for undergraduates or senior high school students. The sentences in the second passage are, on average, 50% longer. Unlike the first passage, the second contains a large number of logically related propositions, linked together by terms such as *For example* (sentence 2), *But* (sentence 3), *and therefore* (sentence 4), *if* (sentence 5) and *This means that* (sentence 6). In earlier work (Gardner, 1975a), such terms have been called *logical connectives*.

Logical connectives: Definitions and examples

Logical connectives are words or phrases that are used to link a proposition with another idea (either a concept or another proposition) to form a more complex proposition. Consider the following examples:

1. A number of important agricultural pests belong to the order of Coleoptera, *for example* the bollweevil and the wireworm.
2. Jack added litmus paper to the test tube in *order to* find out if it contained an acid.
3. Iron rusts more quickly at higher temperatures. *Therefore* ships rust more slowly in the Antarctic than in the tropics.

In Example 1, *for example* acts as a link between the preceding proposition and two subsequent concepts, all within one sentence. In Example 2, *in order to* links two propositions, again within a single sentence. In Example 3, *Therefore* also acts as a link between two propositions, but this time in two different sentences.

Connectives do not belong to any one grammatical category: linkage in English is achieved in a variety of ways. Three of the most common connectives (*and, or, but*) are classified as co-ordinators. However, most connectives belong to a class known as adverbials.* This class is very broad, also encompassing words, phrases and clauses which are not connectives. Formulating a definition which differentiates between non-connective and connective adverbials is not a simple task: it is easier to point to examples than it is to put forward a definition. Consider Examples 4-7.

4. Kangaroos have pouches. The male sea-horse has a pouch, *too*.
5. John carefully added the acid to the metal, *exactly* as in the instructions in the laboratory guide.
6. Scientists do not know how fast gravity travels through space. *Perhaps*, it travels at the speed of light.
7. The rocks were quite soft. *Hence*, they eroded very quickly.

Examples 4 and 5 are both examples of adverbial adjuncts. Example 4 is a focussing adjunct of the additive variety; Example 5 is a focussing adjunct of the restrictive variety. Both focus attention on an earlier proposition; the former adds to the information already given, whereas the latter limits the information already given.

Example 6 is an example of an adverbial disjunct. Whereas adjuncts are integrated into the clause structure of a sentence, disjuncts are not. Example 7 illustrates the adverbial conjunct, and a very large number of logical connectives fall into this category. Whereas disjuncts can serve as answers to questions ("Does gravity travel at the speed of light?" "Perhaps"), conjuncts cannot: there are no questions which can be answered by the word *Hence*.

Although most connectives can be classified as co-ordinators or adverbials, some belong to other categories:

---

* For a recent, comprehensive and modern treatment of English grammar which has had a strong influence on the writing of this section of the paper, see Quirk, Greenbaum, Leech and Svartvik (1972).

8. The iron filings and the powdered sulphur were separated *by means* of a magnet.
9. Some mammals have pouches. *Such* mammals are called marsupials.
10. Some elements, *for example* sodium and phosphorus, react with air and have to be kept away from air.

By means of is a prepositional phrase; *such* is an adjective. The term *for example* in Example 10 is an explicit indicator of apposition. All these terms clearly serve as links between a proposition and a concept or another proposition.

Analysis of a wide variety of sources has yielded a list of eight hundred words and phrases which can act as connectives in English. Of these, about two hundred occur twice or more per 100,000 words in secondary school science books. A list of these more common connectives can be found in an earlier paper (Gardner, 1975a).

Current status of the project

At the time of writing (May, 1976) over 1100 multiple-choice test items have been written in order to assess secondary school students' comprehension of these two hundred connectives. These items have been organized into 28 different trial tests. Each connective is tested in at least four items: two item formats (sentence-completion and gap-filling) for each of two contexts (scientific and every-day). In some cases, the same connective has been tested several times. The items have undergone trial and revision. The final forms, currently being assembled, will be administered to a large sample of Victorian secondary school students in mid-1976.

In addition to pursuing its major purpose, which is essentially to gather data on students' difficulties with connectives, the project is also conducting a number of minor related studies. The purpose of the present paper is to provide a progress report on the major purpose of the project, and to present findings from some of the minor related studies.

Trial data on difficulties

Trial testing has been conducted on groups of about 150 students at Forms 2 and/or 3 level, usually in two or more schools; all 28 tests have now been analysed. Table 1 displays those connectives found in items which have been wrongly answered by at least 30% of the trial sample on both the gap-filling item and the corresponding sentence-completion item. Although the samples were not randomly chosen from the Victorian population, and some of the items are imperfect, the findings do provide a good first approximation to a list of connectives which are demonstrably difficult for a substantial number of secondary school students. The final testing will no doubt yield a more reliable list, but in the meantime, there is clear evidence that substantial numbers of junior high school students find difficulty in comprehending many of the terms which serve to link propositions within written material.

Logical connectives and social class

The three sections which follow describe attempts to investigate the relationships between logical connective ability (LCA) and other variables of interest to educational researchers.

The first study is concerned with the relationship between LCA and socio-economic status (SES).* The impetus for this research comes from Bernstein's (1971) well-known work on language and social class. Bernstein used tape transcripts to study the differences between the speech modes of English middle-class and lower-class boys, and found, *inter alia*, that the middle-

TABLE 1

Difficult logical connectives

again
also
*alternatively
and so
*APPARENTLY
*as (=because)
as (=similarly)
as follows
AS MUCH AS
*as shown by
at least
AT THE SAME TIME
besides
but
but if
BY WAY OF
certainly
CLEARLY
consequently
*CONVERSELY
despite
e.g.
either......or
*ESSENTIALLY
even
evidently
for example
for instance

frequently
from his point of view
FURTHER
FURTHERMORE
generally
*HENCE
here
*i.e.
if......then
IN ADDITION
*IN CONTRAST
*INDEED
in fact
IN GENERAL
in many instances
*in other words
*in particular
*IN PRACTICE
in some ways
instead
in terms of
IN THAT
*in these examples
IN TURN
it follows that
*MOREOVER
namely
nevertheless

NOTICE THAT
now
occasionally
often
on the basis of
only
only if
*RESPECTIVELY
SAY
*SIMILARLY
simply
*simultaneously
SINCE
*SO ALSO
so far
so to speak
STILL
such that
suppose
*THAT IS
the fact that
then
thereby
therefore
thus
together with
*usually
viz
*whereby

Entries are words for which both the sentence-completion and the corresponding gap-filling item have item facilities (percentage correct) ≤ 70%.

* This word proved difficult (facility ≤ 70%) in at least two different sets of items i.e. this represents clearcut evidence of widespread difficulty.

CAPITAL LETTERS indicate extreme difficulty, with item facilities of both the sentence-completion and the gap-filling items ≤ 50%.

---

* This research was conducted by R. Watterson.

class boys tended to use greater proportions of uncommon adverbs and uncommon conjunctions (grammatical groups to which logical connectives belong). Thus one would expect to find class differences in the usage of, and hence the difficulty with, logical connectives. The present study checks that expectation.

Instruments. LCA was measured using one of the trial tests. (In fact, the present study was carried out as a simple extension of the normal trial procedure.) The trial test contained 40 items which had all undergone careful editorial checks and group panelling procedures.

SES was measured by means of an instrument used by Balson (1965) in a study of students in the Geelong area. The instrument permits students to be classified into four SES groups on the basis of father's occupation.

Sample. Five schools in the Melbourne metropolitan area were chosen to provide a wide spread of SES: an independent girls' school, an independent boys' school, a co-ed high school with a good reputation for academic achievement situated in a middle-class SES area, and a co-ed high school and a co-ed technical school situated in the lower SES areas to the north and west of the city. The grade level selected was Form 3 (to ensure a good spread of scores on LCA), and in those schools in the sample which practised streaming (four of the five), the most academically capable stream was selected. This yielded a sample of 172 students; the father's occupation of seven of these could not be classified, reducing the sample to 165. The 165 students were then categorized into Classes A (highest SES), B, C and D, containing 22, 33, 56 and 43 students respectively.

Analysis. The LCA test was subjected to the usual item analysis procedures, yielding item facilities (percentage correct) and point biserial correlation coefficients (r_{pbis}), which measure the extent of agreement between the skill measured by the item and the skill measured by the rest of the test. In addition, the performances of the four SES groups on each item were compared, and χ^2 with Yates' correction was used to test the null hypothesis that there was no association between LCA, as measured by frequency of correct response on the individual item, and SES.

Findings. The findings are presented in Table 2. Seventeen of the 40 items were very easy, with facilities at or above 90%; as nearly every student in the sample is getting these items right, they cannot be expected to differentiate amongst SES groups at this particular grade level. Fifteen of the items had low to moderate r_{pbis} values (less than .40); if LCA is a fairly monogeneous internally consistent intellectual skill, then these items are not particularly good measures of it. Of the 23 items which were moderately difficult and of the 25 items which were internally consistent, 15 were both moderately difficult and internally consistent. These items are asterisked in the fifth column of the table. If one were aiming to construct a norm-referenced test designed to yield a reliable spread of scores measuring LCA, these 15 would constitute "good" items.

The final column of Table 2 shows the probability values associated with the χ^2 values, which estimate the association between LCA, as measured by the item, and SES. Thirteen of the 40 items discriminate amongst the various SES groups; the degree of overlap between these items and the 15 "good" items is quite striking.

Of course, there are some weaknesses in the design of this study. The test was only a trial test; the same sample used to evaluate the validity of the items was used to test the relation-

TABLE 2

Item statistics for trial test 6

Item No.	Connective	Facility	r_{pbis}	Good item?	p for $\chi^2 <$
1	though	77%	.39		
2	provided that	98	.38		
3	indeed	42	.28		
4	in order to	94	.46		
5	whereas	87	.50	•	.01
6	thus	76	.59	•	.001
7	perhaps	88	.24		
8	in other words	76	.42	•	
9	yet	95	.34		
10	other than	89	.47	•	
11	consequently	72	.43	•	.05
12	for example	67	.39		
13	but	88	.59	•	.01
14	thereby	80	.52	•	.01
15	but if	79	.55	•	.01
16	in fact	88	.22		
17	nevertheless	76	.46	•	.05
18	while	90	.40		
19	since	87	.36		
20	or	90	.36		
21	because	95	.26		
22	respectively	62	.44	•	.001
23	as if	95	.45		
24	eventually	87	.30		
25	much like	98	.41		
26	in addition	80	.50	•	.001
27	due to	92	.48		
28	whenever	98	.21		
29	therefore	90	.44		
30	furthermore	82	.46	•	
31	although	93	.44		.05
32	now	91	.22		
33	and so	90	.50		
34	next	85	.58	•	.01
35	however	90	.50		
36	just as	94	.54		
37	moreover	7	.18		
38	hence	55	.56	•	.001
39	on the other hand	95	.24		
40	for the same reason	81	.47	•	.05

ship between LCA and SES; other factors such as intelligence and school facilities which are confounded with SES were not statistically controlled. Nevertheless, there is strong support, completely in line with Bernstein's findings, for the contention that children from high SES homes demonstrate higher LCA than do children from lower SES homes; comprehension of a number of logical connectives – e.g. *thus, respectively, in addition,* and *hence* – is markedly different amongst children of differing socio-economic status. Such differences are quite possibly due to differences in patterns of language usage. There is nothing in these findings to suggest that the differences are due to irremediable, permanent defects. This point needs to be made in view of some of the gross misinterpretations that have been made of Bernstein's ideas.

LCA and cognitive preferences*

A cognitive preference test (CPT) attempts to measure relative interest in different kinds of information. A typical CPT item contains an introductory stem, followed by four correct statements, reflecting preference for *memory* (restatement of facts or terms) (M), for practical *application* (A), for critical *questioning* (Q), and for fundamental *principles* (P). The respondent is asked to select the statement that most appeals to him.

In her review of CPTs in science, Brown (1975) suggests that

> It is possible that pupils, on expressing preferences between statements, are attending to differences in linguistic features (formal characteristics of vocabulary and syntax) rather than differences in meaning. ...... and systematic choices might reflect characteristics of the language with which they are familiar.

Analysis of six CPTs containing science items (Heath, 1964; Atwood 1967/8; Mackay, 1971, undated, 1975; Kempa & Dubé, 1973) shows that they contain many logical connectives, and that these connectives are unequally distributed in both frequency and type amongst Q,A,P and M statements. For example, in a total of 115 different CPT items, logical connectives were found to occur 51 times in Q-statements, 34 times in A-statements, 37 times in P-statements, but only 14 times in M-statements. When one examines the number of different logical connectives used, the figures for Q,A,P and M are 28,22,25 and 11 respectively. If one makes a distinction (admittedly based on subjective judgement) between common connectives (e.g. *when, if, since, because*) and uncommon connectives (e.g. *hence, according to, in that, as a rule*), uncommon connectives occur 18,12,16 and 5 times in Q,A,P and M statements.

Figures such as these raise the question of whether LCA is related in some way to cognitive preference. Is cognitive preference to some extent a manifestation of underlying linguistic skills? Do students who misunderstand a particular logical connective avoid choosing statements in a CPT which contain that connective? An investigation of questions such as these constitutes the purpose of this study.

Tests. Two CPTs were constructed out of items taken from existing CPTs. Items were selected or rejected on the basis of five criteria:

(1) items not containing any logical connectives were omitted;

---

* Myint Thein co-operated in the planning and execution of this study.

(2) items with logical connectives known to be very easy were omitted;

(3) items containing a large amount of difficult technical language were omitted, in view of the sample selected for the study;

(4) items selected for inclusion had to form a representative sample of the set of logical connectives used in all the published CPTs;

(5) items were selected to represent various scientific fields such as physics, chemistry and biology.

A large set of items met these criteria, enough to form two separate tests (CPT1 and CPT2), each containing 24 items. In CPT1, the logical connective occurred nine times in Q-statements, five times in A-statements, eight times in P-statements, and twice in M-statements. The distribution in CPT2 was almost identical. These distributions are not arbitrary: they faithfully reflect the relative frequencies of occurrence of uncommon logical connectives in the population of CPT items analysed.

Two logical connective tests (LCA1 and LCA2) were also developed, with each containing 24 items. There was a one-to-one correspondence between CPT items and LCA items e.g. Item 8 in CPT1 contains the connective *in that*; Item 8 in LCA1 tests the comprehension of this connective. LCA items were obtained from the item bank of the major project; in some cases grammatical modification was necessary to make the structure of the sentence in LCA item similar to that of the statement in the CPT item; in a small number of cases, fresh items were written.

Sample. Students at Form 4 level were chosen for the study, in order to obtain a sample that could probably comprehend the science content of the CPT, but would display some variability in LCA. Four high schools in the predominantly middle-class south-eastern suburbs of Melbourne were chosen; in each school, two classes taking science were selected.

Research Design. The existence of two forms of each test permitted two separate experimental runs. These were conducted simultaneously, with students in alternate seats answering either CPT1 + LCA1 or CPT2 + LCA2.

Because the LCA tests measure comprehension of the logical connectives encountered in the CPT test, there is the possibility of a type of practice effect occurring. For example, answering the LCA test first might facilitate comprehension of the connective being tested, and hence affect in some way the choice on the subsequent CPT test. On the other hand, answering the CPT test first might facilitate performance on the LCA. In order to exert some control over these possible effects, a counter-balanced design was adopted: in each school, one class was given the CPT test first, then the LCA test, while the other class was given the tests in reverse order.

The tests were administered consecutively during a one-hour period. The normal class teacher supervised the testing, (with Myint Thein present in the classroom.)

Analysis. Analysis of the data was carried out at three levels: total-test, sub-scale and individual-item. At the total-test level, the total number of times that each student chose a cognitive preference statement containing the logical connective was found. The correlation between this set of measures and total scores on the corresponding LCA test was then determined. At the sub-scale level, the 24 CPT items were divided into four sub-scales, Q,P,A and M. For example, the Q-scale contains those items which the logical connective is embedded in a Q statement. The LCA test was then divided into the four corresponding sub-scales. The correlations between the four CPT/LCA sub-scale pairs were then found. Finally, at the individual-item level, students were cross-tabulated on the basis of choosing/not choosing the CPT statement containing a logical connective, and right/wrong on the LCA item testing that connective. The phi-coefficient was then used to determine the association between cognitive preference and LCA.

Findings. The correlation-coefficients and the phi-coefficients were all close to zero i.e. the present study provides no evidence to support the view that linguistic skills measured by the LCA items influence, in any way, students' choices on CPT items. It may be, of course, that there really *is* an association between these two variables, but that in the present study the Grade 10 students responded largely at random to the choices in the CPT items. (They were certainly not responding at random to the LCA items: the two LCA tests had Kuder-Richardson-20 reliabilities of .84 and .87). Be that as it may, the null finding of the present study would lend some support to CPT researchers, inasmuch as no evidence has yet been found to "explain away" cognitive preferences in purely linguistic terms.

LCA and attitudes to the PSSC text book*

For the past decade, the various editions of the PSSC text have served as the prescribed reference for senior secondary school physics courses in Victoria. Anecdotal evidence gathered during this time suggests that many students find the book verbose and difficult to understand, and evaluate it in rather negative terms.

It would therefore be of interest to know whether any relationship exists between attitudinal factors (positive/negative emotional reaction to the PSSC text) and cognitive/linguistic factors (e.g. students' LCA). Students with higher LCA might be expected to experience less difficulty at comprehending the many complex sentences in the text, and therefore might be more favourably inclined towards it. This might lead one to expect a positive correlation between LCA and attitudes to the PSSC text. However, there is an extensive literature (reviewed by Gardner, 1975b) showing a generally low or even zero correlation between cognitive and affective variables.

Variables. Attitude to the PSSC text was measured by means of an untried 20-item Likert scale with a potential range of -40 to +40. (Sample items: "I think the PSSC text is easy to understand", "The PSSC textbook is boring and dull".) This scale was embedded in a 40-item instrument, the other items comprising ten items measuring attitude to non-authoritarian ("discovery") modes of learning and ten items measuring enjoyment of physics. These items were taken from the Physics Attitude Index (Gardner, 1972).

LCA was measured by means of a 40 item test, made up of items which had undergone trial (on students in Grades 8 and 9). Because the study was conducted at Higher School Certificate (Grade 12) level, the most difficult questions in the item bank were selected for the purposes of the present study, in order to produce a test that would be sensitive at the higher grade level.

---

* This study was conducted with the assistance of L. Schafe.

Sample. HSC Physics students (N=93) in six metropolitan high schools provided data for the study. The schools were not randomly sampled from a specified population; they were chosen on the basis of the availability of direct personal contact via Dip.Ed. and higher degree students. Testing was conducted in April, i.e. in the third month of the school year.

Findings. Test statistics for the three attitude scales and the LCA test, and their intercorrelations, are presented in Table 3. It can be seen that attitudes to the textbook are moderately correlated with enjoyment of physics and with attitude to discovery learning, but are uncorrelated with LCA. Inspection of the mean attitude scale scores suggests that the students in the sample were, on average, fairly neutral in their attitude to discovery learning, and mildly favourable towards the PSSC text; they expressed a fairly strong level of enjoyment of physics. The average student successfully answered three-quarters of the LCA items. Items testing the following words proved difficult to more than 30% of the sample: *apparently, in addition, so to speak, thus, instead, according to, further, viz, now* (in the sense of "note that"), *moreover, clearly, conversely*.

TABLE 3

Attitude scale and LCA test statistics

Scale	No. of items	$\bar{X}$	σ	Cronbach alpha	Correlation with scale		
					2	3	4
1. Attitude to discovery learning	10	+0.9	5.7	.63	.25*	.16	.09
2. Attitude to textbook	20	+4.4	11.2	.86		.34**	.01
3. Enjoyment of physics	10	+7.9	5.4	.73			.11
4. LCA	40	29.7	6.6	.87			

* $p < .02$ ** $p < .01$

These findings are interesting, but the main purpose of the study was, of course, to investigate the relationships between attitudes to the textbook and LCA. As already mentioned, the data show no relationship i.e. there is no evidence from the present study that ability to comprehend logical connectives determines a student's attitude to the PSSC text. Yet students do vary widely in their attitude to the text (attitude scores ranged from +26 to -26). The question therefore remains: what aspects of the book, or what characteristics of students (or both) cause some students to evaluate the text in negative terms?

Future work

The main thrust of the present project is, of course, to obtain a comprehensive picture of secondary school students' difficulties with logical connectives. This work should be completed by early 1977. The obvious next step is to develop teaching materials to help strengthen students' LCA where necessary.

As to further research in this area, at least two areas might be profitably explored. One is the possible relationship between LCA and students' methods of processing verbal information, a question raised in an earlier paper (Gardner, 1975a). Some data from the more recent research is interesting here. Responses to one attitude-to-discovery item – "When you learn a new law in physics it is very important to thoroughly learn the statement of it so that you know it word perfectly" – correlated significantly (r = .24) with total LCA score, the more able students tending to disagree with the attitude item. This suggests that students who favour rote learning techniques are less able at comprehending the logical links between propositions.

A second area is to explore further the ways in which logical connectives are used by teachers and pupils in classroom discourse. There is some evidence that this might be a fruitful area: Nuthall (1970) reports research by Rosenshine showing that teachers who were more effective at explaining ideas to pupils made greater use of linking words (i.e. logical connectives) such as *because, therefore, in order to, consequently, by means of, since,* etc.

Clearly there is much scope for both research and development in this field.

Acknowledgements

One of the pleasures of working on a funded research project in a large institution is the opportunities given to bring together many different people, each with their own set of abilities and interests, who can contribute usefully to the development of the project. Apart from my co-authors, I would like to express my appreciation of the work of Sue Taylor (my research assistant), Eileen Badrian (my typist), and to the many principals, teachers and pupils who are participating in the project. And, as usual, thanks are due to the AACRDE (now called the Education Research and Development Committee) for their continued support.

References

ATWOOD, R.K. "A cognitive preference examination using chemistry content." *Journal of Research in Science Teaching,* **5**: 34-35, 1967-8.

BALSON, M. *The effects of social class membership on certain aspects of school performance and educational expectations of students and parents in the Geelong area.* Monash University, Faculty of Education, 1965.

BERNSTEIN, B. *Class, codes and control,* (Vol. 1: Theoretical studies towards a sociology of language). Routledge and Kegan Paul, London, 1971.

BROWN, S.A. "Cognitive preferences in science: Their nature and analysis." *Studies in Science Education,* **2**: 43-65, 1975.

GARDNER, P.L. *Attitudes to physics.* Ph.D. thesis, Monash University, 1972.

GARDNER, P.L. "Logical connectives in science: A preliminary report." *Research in Science Education,* **5**: 161-176, 1975(a).

GARDNER, P.L. "Attitudes to science: A review." *Studies in Science Education,* **2**: 1-41, 1975(b).

HEATH, R.W. *Cognitive preference text: High school physics.* Education Testing Service, Princeton, New Jersey, 1964.

KEMPA, R.F. & DUBÉ, G.E. "Cognitive preference orientations in students of chemistry." *British Journal of Educational Psychology*, **53**: 279-288, 1973.

MACKAY, L.D. *Cognitive preferences and achievement in physics.* Ph.D. thesis, Monash University, 1971.

MACKAY, L.D. *Chemistry preference test.* Schools Council Science Evaluation Project, undated.

MACKAY, L.D. "Cognitive preferences and achievement in physics, chemistry, science and mathematics." *Research in Science Education*, **5**: 49-58, 1975.

NUTHALL, G.A. "A review of some selected recent studies of classroom interaction and teaching behaviour", in J.J. Gallagher, G.A. Nuthall & B. Rosenshine, *Classroom Observation AERA Monograph Series on Curriculum Evaluation*, Rand McNally, Chicago, 1970.

QUIRK, R., GREENBAUM, S., LEECH, G. & SVARTVIK, J. *A grammar of contemporary English.* Longman, London, 1972.

CLASSROOM CLIMATE AS PREDICTOR AND CRITERION IN SCIENCE EDUCATION RESEARCH

Barry J. Fraser

Introduction

In science education research in recent years, there has been a sharp rise in the frequency of use of classroom climate dimensions, both as predictor and criterion variables. In employing classroom climate dimensions as predictor variables, researchers have attempted to improve the prediction of pupil learning outcomes by a knowledge of classroom climate characteristics (see Walberg and Anderson, 1968a; Walberg, 1969a; Welch and Walbert, 1972). When classroom climate variables have been used as criterion variables, researchers have sought to judge the efficacy of alternative instructional treatments in terms of their effectiveness in promoting a favourable classroom climate (see Grobman, 1968; Welch, 1969; Anderson and Walberg, 1974).

Aim. The present paper describes the use of classroom climate measures, both as predictor and criterion variables in research related to the Australian Science Education Project (ASEP). In an earlier paper, Fraser (1975) described the relationship of various learning outcomes to instruction (ASEP/control) and to aptitudinal variables (SES, IQ and sex) among a sample of Melbourne seventh graders. In the analyses in this paper, classroom climate data will be added to the data in the previous paper, with a vew to examining the increment to the variance in learning outcomes associated with the addition of climate measures, and to comparing the classroom climates of ASEP and non-ASEP classrooms.

The ASEP group in the present study consisted of classes which used ASEP materials exclusively throughout a year, with the choice, sequencing and timing of units being decided upon by the teachers involved. The control group consisted of classes using any non–ASEP materials during the year. The learning outcome pre-tests and post-tests were administered in March and October, respectively, while the classroom climate measures were administered during August. This timing of the collection of classroom climate data allowed climate to be used, not only as a predictor of changes in learning outcomes during the year, but also as a criterion on which to compare the influence of ASEP and non-ASEP instructional strategies over the time between the beginning of the school year and August.

The sample. A distinction between the analyses to be reported here and those in Fraser (1975) is in the samples of pupils involved. Because of the somewhat exploratory nature of the present investigation involving classroom climate variables, it was thought that a sample as large as the 46-school sample used previously was not warranted. Consequently, in order to economize with testing and analysis, it was decided that the investigation employing classroom climate variables would be conducted for a sample of 20 classes drawn from the original 46 Melbourne coeducational high schools.

A sample of 10 ASEP schools and 10 control schools was selected from the original sample of 46 schools. These schools were selected so that the ASEP group and the control group would each consist of a set of schools representative of the various geographic and socio-economic areas of Melbourne, and so that the two groups of teachers would be closely comparable with respect to age, qualifications and male-female ratio. Furthermore, analyses conducted after the sample had been drawn indicated that this ASEP group and control group did not differ significantly on SES, IQ, sex and each of 17 learning outcome pre-tests. Consequently, it was concluded that the ASEP and control groups described above were comparable on at least a reasonable number of school, teacher and pupil attributes. Table 1 describes the actual sample in more detail showing the number of schools, pupils and class aptitude cell sampling units in the ASEP group and in the control group. For the reasons outlined in some detail in Fraser (1975), the class aptitude cell has been adopted as the unit of statistical analysis in the present study.

TABLE 1

Sample sizes for analyses employing Classroom Climate Scales

Group	Sample Size		
	Classes	Pupils	Class aptitude cells
ASEP	10	266	76
Control	10	265	77
Total	20	531	153

Measuring classroom climate

Learning Environment Inventory. The instrument which has been employed most frequently to measure classroom climate is the *Learning Environment Inventory* (LEI) developed by Walberg and Anderson (see Anderson, 1971). Anderson and Walberg (1974) have reported that 200 investigators in nine different countries requested copies of the LEI, while Randhawa and Fu (1973) estimated that 300 researchers in 10 different countries were using the LEI in 1973. At present, however, much of this research has not yet been published in the literature, with the exception of a group of studies related to Harvard Project Physics. Examples of Harvard Project Physics studies which have used classroom climate dimensions as independent variables are Walberg and Anderson (1968a), Anderson and Walberg (1968), Walberg (1969a), Walberg (1969b), Anderson (1970), and studies which have used classroom climate dimensions as dependent variables are Walberg and Anderson (1968b), Walberg (1968) and Walberg and Ahlgren (1970). It is also interesting to note that two other studies in the present volume have employed modified versions of the LEI, one using climate dimensions as independent variables (Power & Sadler, 1976) and the other using climate dimensions as dependent variables (Northfield, 1976).

The development of the LEI, which began as part of the research and evaluation activities of Harvard Project Physics, proceeded in three identifiable stages. The first version of the LEI, then called the Classroom Climate Questionnaire, was developed by Walberg and patterned on the work of Hemphill and Westie (1950) and Hemphill (1956). After administration of this version to senior high school students (e.g. Walberg & Anderson, 1968a; Anderson & Walberg, 1968), content, item and factor analyses were employed by Walberg and Anderson as the basis for the writing of a second version of the LEI. Data from the administration of the second version (e.g. Anderson, 1970) was used, in turn, as the basis for the development of the third and final version, described in detail in Anderson's (1971) LEI test manual.

The final version of the LEI consisted of 105 items which had a four-point Likert response format. These 105 items were divided amongst the following 15 scales, with seven items in each scale: Cohesiveness, Diversity, Formality, Speed, Environment, Friction, Goal Direction, Favoritism, Difficulty, Apathy, Democracy, Cliqueness, Satisfaction, Disorganization and Competitiveness. These 15 climate scales, whose items are fully listed in Anderson's (1971) manual, are reported to have alpha reliability coefficients ranging from 0.53 to 0.85 with a median of 0.72 for a sample of 1,048 senior high school pupils (Anderson & Walberg, 1974, pp. 84-85).

While the LEI has proved suitable in past research involving senior high school students, there are reasons to doubt the suitability of the LEI in its original form for use with the seventh grade pupils involved in the present study. Firstly, since the LEI was originally developed for use at the senior high school level, readability and suitability for the Form 1 level could not be assumed. Problems with readability were in fact encountered by Power and Tisher (1975) who found that Australian Grade 9 pupils did have difficulty comprehending certain of the original items in the LEI. The second problem with the LEI was that, because ASEP is individualized and self-paced, there was some doubt whether the LEI would contain those climate dimensions that would be of most relevance in ASEP classrooms.

Anderson and Walberg (1974, p. 84) have suggested that, instead of always using all 15 LEI scales, the researcher could exclude those scales of lesser relevance to his particular study. Accordingly, it was decided to achieve a certain degree of economy by excluding from consideration those LEI scales of lesser relevance to the ASEP situation and those scales which appeared unsuitable, even if items were reworded, for use with seventh grade pupils.

Modifications to the LEI. A panel of people, who had expertise in science education and educational measurement and who were familiar with ASEP, was convened to seek consensus of opinion about which LEI scales should be omitted. Certain scales, such as the *Democracy* scale which measures whether class activities are decided upon by the class as a whole, were deemed inappropriate in the ASEP situation where pupils' work is individualized. Other scales, such as the *Friction* scale which includes items containing phrases such as 'undercurrent of feeling' and 'constant bickering' were omitted because it was considered impossible to reword items readily to make them easily comprehensible to seventh grade pupils. After a number of LEI scales were omitted for the above reasons, the following nine scales remained as being potentially suitable for inclusion in the final study: *Diversity, Formality, Speed, Environment, Goal Direction, Satisfaction, Disorganization, Difficulty and Competitiveness.*

The panel of experts suggested three further modifications to the remaining LEI scales. Firstly, numerous items were reworded in an attempt to improve readability for seventh grade pupils. In this rewording of items, valuable assistance was obtained from a version of the LEI which had been reworded by Power and used as the post-test in a study described in Power and Tisher (1975). Secondly, it was agreed that the LEI had omitted a climate dimension of paramount importance in the ASEP situation, namely the extent to which pupils perceive their

TABLE 2

Number of items in, alpha reliability of, and intercorrelations between each Classroom Climate Scale

Scale	No. of Items	Cronbach alpha Reliability	Scale Intercorrelations								
			Div	Sp	Env	Goal	Sat	Dis	Diff	Comp	Ind
Diversity	4	0.50	1.00	0.00	0.09	-0.05	-0.11	0.03	0.03	0.03	-0.05
Speed	6	0.66		1.00	-0.35	-0.30	-0.31	0.39	0.36	0.27	-0.07
Environment	6	0.63			1.00	0.32	0.26	[illegible]0.41	-0.24	-0.23	0.04
Goal Direction	7	0.62				1.00	0.43	-0.42	-0.26	-0.09	0.07
Satisfaction	6	0.80					1.00	-0.48	-0.34	-0.05	0.10
Disorganization	6	0.66						1.00	0.33	0.29	0.11
Difficulty	5	0.50							1.00	0.23	-0.02
Competitiveness	5	0.53								1.00	0.12
Individualization	10	0.71									1.00

work as individual and selfpaced. A number of items were therefore written to tap this dimension and the resulting scale was called *Individualization*. Thirdly, it was felt that the word 'class' appearing in the original LEI should be replaced by 'science class' in an attempt to help focus pupils' attention specifically on their science classes. Accordingly, the phrase 'science class' was used throughout all scales and the new instrument was named the *Science Class Inventory*.

The Science Class Inventory was administered at the end of second term, 1974, to the sample of 541 seventh grade pupils described in Table 1. After employing the statistical validation criteria of internal consistency, uniqueness and sensitivity, outlined in Fraser (1974), the original item pool was reduced to 55 items. It was found that one of the original scales, *Formality*, had to be eliminated altogether because of its unsatisfactory statistical characteristics. Table 2 shows the number of items in, the alpha reliability of, and the intercorrelations between each classroom climate scale in the refined version of the *Science Class Inventory*.

Classroom climate as predictor of learning outcomes

Walberg's claim. Walberg has proposed a model, $L_h = f(I_i, A_j, E_k)$, in which learning outcomes, L_h, have been conceptualized as a function of three distinct construct domains, namely instructional variables, I_i, aptitudinal variables, A_j, and environmental variables, E_k (see Walberg, 1970; Fraser, 1975). Walberg's essential claim was that environmental variables could contribute appreciably to the amount of variance explained in learning outcomes over and above that explained by instructional and aptitudinal variables alone.

In order to investigate Walberg's claim, it was decided to compare the amount of variance explained in various learning outcomes by a model excluding classroom climate variables with one including climate variables. Table 3 provides findings relevant to this investigation. The first column in Table 3 lists the 17 learning outcome scales described in detail in Fraser (1974). Of these 17 scales, the first nine measure enquiry skills, the next three measure aspects of understanding of the nature of science and the remaining five measure various attitudes. The second column of Table 3 shows the percentage of variance in each learning outcome post-test explained by the 16-term regression model used in the previous study involving 1,158 pupils (see Fraser, 1975). This smaller model includes pre-test, instruction (ASEP/control), seven aptitudinal variables (SES, IQ, sex and their four possible interactions) and the seven possible instruction-aptitude interactions. The last column in Table 3 shows, for the sample described in Table 2, the amount of variance in each learning outcome explained by a larger regression model which contains, as well as the 16 terms present in the smaller model, the nine classroom climate dimensions of the Science Class Inventory and nine instruction-climate interactions.

Table 3 indicates that for all 17 learning outcomes considered, the addition of classroom climate (and instruction-climate) variables has increased appreciably the amount of variance explained. In fact, the percentage of variance explained in different learning outcomes ranged from 22.1 to 62.2 with a median of 41.0 per cent for the model excluding climate variables, but ranged from 42.8 to 67.7 with a median of 51.4 per cent for the model including climate variables. Table 3, then, lends support to Walberg's basic contention that environmental variables can account for an increment in the variance explained in learning outcomes over and above that explained by instructional and aptitudinal variables alone.

TABLE 3

Percentage of variance (R^2) accounted for in each of 17 learning outcome post-tests by a regression model excluding and including Classroom Climate variables

Learning Outcome	R^2 (%) for Model Excluding Climate Variables[a]	R^2 (%) for Model Including Climate Variables[b]
TOES 1 (Library)	48.3	54.1
TOES 2 (Index)	43.9	61.3
TOES 3 (Scales)	55.2	58.7
TOES 4 (Averages)	62.2	64.0
TOES 5 (Charts)	53.5	56.3
TOES 6 (Graphs)	48.3	52.0
TOES 7 (Compr)	52.1	67.7
TOES 8 (Exptl)	41.0	53.8
TOES 9 (Concl)	49.1	61.9
TOUS P (Philos)	33.5	46.4
TOUS H (Hist-soc)	35.3	44.2
TOUS N (Normal)	35.8	52.0
Att. S (Soc imp)	22.1	42.8
Att. E (Enjoy)	35.6	66.0
Att. I (Interest)	37.3	62.4
Att. to Enquiry	22.6	47.5
Scientific Atts.	32.4	52.3
Median R^2 (%)	41.0	54.1

[a] Model excluding climate variables contains the following 16 predictors: pre-test, instruction (ASEP/non-ASEP), seven aptitudinal variables (SES, IQ, sex, 4 interactions) and seven instruction-aptitude interactions.

[b] Model including climate variables contains 34 predictors: the 16 predictors listed above, nine climate dimensions and nine instruction-climate interactions.

Partitioning the variance of the full model. While Table 3 provides data about the contribution to variance in learning outcomes made by the full 34-term regression model, it provides no information about how the variance of the full model may be partitioned amongst the different predictors. In particular, it would be of interest to obtain estimates of the relative unique contributions to variance in learning outcomes made by each of the five clusters of variables, namely the instructional variable (I_i), the seven aptitudinal variables (A_j), the nine environmental variables (E_k), the seven instruction-aptitude interactions (I_iA_j) and the nine instruction-environment interactions (I_iE_k).

Of course, with nine classroom climate variables, the number of possible interaction terms involving a climate variable would be vast. The inclusion of this vast number of interactions in the present analysis, however, was thought inappropriate for several reasons. Firstly, the interpretation of such a large number of interactions, many of very high order, would be almost impossible. Secondly, it would be easy to exhaust all available degrees of freedom if a large number of the interactions was included in the full regression model. Thirdly, the computational procedures would be excessively cumbersome. Attention was therefore restricted to the nine interactions between instruction and a classroom climate variable as these were thought to be of particular importance in examining the relative effectiveness of ASEP and control materials when used in different learning environments.

The task of partitioning the variance of the full model amongst the various I_i, A_j, E_k, I_iA_j and I_iE_k predictors is not a simple matter. There is evidence to suggest that A_j and E_k variables are likely to be correlated (see Coleman's (1966) *Equality of Educational Opportunity* study), that the E_k variables are intercorrelated (see Table 2), and that some A_j variables are likely to be intercorrelated (e.g., SES and IQ). Because of correlations amongst predictor variables, the variances in learning outcomes attributable to different predictors would overlap and the independent contribution made by each predictor could be estimated in a variety of different ways.

For the present analyses, Overall and Spiegel's (1969) Method 2 was chosen as the algorithm for partitioning the variance of the full model. However, as this method has been described in detail elsewhere (McArthur, West and Fraser, 1975), it will not be discussed here. It should be noted also that, in performing the multiple regression analyses via Method 2, statistical power was maximized by maintaining IQ, the climate scales and various interactions as continuous variables instead of reducing them to categorical data. Table 4 shows the results, for each learning outcome separately, of the use of Method 2 in partitioning the variance of the full model amongst the different blocks of predictor variables.

Results. The first column in Table 4 shows the percentage of variance in each learning criterion accounted for by the full 34-term regression model, the next column shows the variance explained by the pre-test (the square of the simple correlation) and the next five columns show the percentages of variance uniquely explained by I_i, A_j, E_k, I_iA_j and I_iE_k variables, respectively. Table 4 indicates that pre-test performance accounted for a median of 28.0 per cent of variance in a learning outcome, while I_i, A_j and E_k variables accounted uniquely for a median of 0.2, 5.8 and 5.9 per cent of variance, respectively. That is, while the instructional variable tended to make only a small independent contribution to the variance in learning outcomes, aptitudinal and environmental blocks of variables each made a relatively substantial independent contribution. Table 4 also shows that the block of I_iA_j and I_iE_k interactions accounted for medians of 2.1 and 3.2 per cent of variance in learning outcomes, respectively. That is, although instruction-aptitude and instruction-environment interactions made a smaller independent contribution to variance in learning outcomes than either the A_j or E_k block of main effects, the I_iA_j and I_iE_k interactions, nevertheless, made some contribution to variance which was independent of pre-test and I_i, A_j and E_k main effects.

The right-hand half of Table 4 shows the significant relationships which emerged between a learning outcome and individual E_k or I_iE_k predictors. In order to reduce the number of Type II errors which could arise in performing all 306 possible F tests, a condition was applied prior to calculating F values for any individual E_k or I_iE_k variable. F tests for individual E_k variables were only performed if the hypothesis of no relation between a learning outcome and the E_k cluster could be rejected at the alpha = 0.1 level. F tests for individual

TABLE 4

Percentage of variance in each learning outcome post-test explained by the full regression model, pre-test, instruction (I_i), seven aptitudinal variables (A_j), nine environmental variables (E_k), seven instruction-aptitude interactions (I_iA_j) and nine instruction-environment interactions (I_iE_k)

Criterion \ R^2(%)	Full Model	Pre	I_i	A_j	E_k	I_iA_j	I_iE_k	Significant Individual E_k and I_iE_k Predictors: Div	Speed	Env	Goal dir	Satis	Disorg	Diff	Comp	Indiv	Interactions
TOES 1 (Library)	54.1	39.4	1.4	3.8	4.6	1.6	2.1										
TOES 2 (Index)	61.3	38.9	0.1	9.1	6.4	2.0	4.3			2.5**							
TOES 3 (Scales)	58.7	40.1	0.4	9.8	2.7	1.6	2.3										
TOES 4 (Averages)	64.0	48.2	0.0	5.0	4.9	1.0	2.3				L1.3*			L1.5*			
TOES 5 (Charts)	56.3	27.7	0.1	6.9	4.6	3.1	2.9										
TOES 6 (Graphs)	52.0	29.6	0.0	6.6	5.1	2.0	4.4										
TOES 7 (Compr)	67.7	47.2	0.1	2.9	9.1	2.5	3.2	2.0**								L2.1**	
TOES 8 (Exptl)	53.8	22.2	0.2	19.7	5.9	1.7	3.4				2.2*						
TOES 9 (Concl)	61.9	37.9	4.4	6.4	5.6	3.0	3.0								L2.0**		
TOUS P (Philos)	46.4	27.2	0.3	7.9	3.1	2.2	3.9										
TOUS H (Hist-soc)	44.2	24.3	0.9	7.9	5.4	0.7	2.6										
TOUS N (Normal)	52.0	35.9	0.3	3.7	6.0	1.2	2.8										
Att. S (Soc imp)	42.8	17.0	0.5	4.0	13.2	2.1	6.1										
Att. E (Enjoy)	66.0	28.0	0.0	3.5	26.1	2.9	2.8		L1.3*			5.3***					
Att. I (Interest)	62.4	20.3	0.6	5.0	25.8	6.4	3.7					6.4***		4.7***			
Att. to Enquiry	47.5	22.9	0.2	5.8	9.3	2.3	6.8										2.9** (I_i × Diff) 2.3* (I_i × Indiv)
Scientific Attts.	52.3	25.2	0.0	4.7	8.2	3.0	7.1		2.1*	1.6*				L5.0**			2.1* (I_i × Div)
Median R^2	54.1	28.0	0.2	5.8	5.9	2.1	3.2	0.3	0.5	0.5	0.2	0.3	0.1	0.4	0.1	0.3	0.0

$* p < .05$, $** p < .01$, $*** p < .001$ L Lower climate scores associated with higher learning outcome scores

I_iE_k interactions were only performed for a particular learning outcome if one of the following three conditions could be met: firstly, if the hypothesis of no relation between that learning outcome and the I_iE_k cluster could be rejected at the alpha = 0.1 level; secondly, if the hypothesis of no relation between that learning outcome and the individual I_i variable could be rejected at the alpha = 0.05 level; thirdly, if the hypothesis of no relation between the learning outcome and an individual E_k variable could be rejected at the 0.05 level. The right-hand part of Table 4 shows the percentages of unique variance explained in various learning outcomes by individual E_k or I_iE_k variables for which the above conditions were met and for which the hypothesis of no relation for that individual predictor was also rejected at the alpha = 0.05 level. It should also be emphasized that the percentage of variance for each individual E_k variable shown in Table 4 is independent, not only of pre-test and I_i and A_i variables, but also of the other classroom climate variables.

Table 4 indicates that 14 significant relationships emerged between a learning outcome and an individual classroom climate scale, and that three significant I_iE_k interactions emerged. The interpretation of the 14 significant relationships between an E_k variable and a learning outcome can best be illustrated by an example. Table 4 indicates that the speed dimension accounted uniquely for 1.3 per cent of the variance in performance on Attitude E (Enjoyment of science lessons), and that this contribution was significant at the 0.05 level. It was found that pupils in classrooms perceived as less speeded, experienced a more favourable change in enjoyment of science lessons during the year, relative to pupils in classrooms perceived as more speeded. An inspection of plots of predicted scores indicated that the first two significant I_iE_k interactions in Table 4 (namely I_i x *Difficulty* and I_i x *Individualization* both for the *Attitude to Enquiry* scale) had a similar interpretation. Whereas positive attitude to enquiry in the ASEP group tended to decrease with level of perceived difficulty or individualization, positive attitude to enquiry in the control group tended to increase with the perceived difficulty or individualization of the class. The interpretation of the I_i x *Diversity interaction* for the *Scientific Attitudes* scale was that, while the extent to which the ASEP group adopted scientific attitudes tended to be almost independent of the perceived diversity of the class, the extent to which the control group adopted scientific attitudes tended to increase with the level of perceived diversity.

Classroom Climate as criterion of instructional effectiveness

Whereas the analyses in the previous section involved the use of nine classroom climate variables as predictors of learning outcomes, consideration in this section will turn to the use of the same classroom climate dimensions as criteria against which the effectiveness of alternative instructional strategies might be evaluated. It should be noted that ASEP's philosophy has been stated, not only in terms of desirable learning outcomes, but also in terms of the sort of learning environment considered desirable (ASEP, 1974). For example, ASEP's approach is intended to foster a learning environment in which a pupil's work is individualized, self-paced and enquiry-centred. It would be interesting, therefore, to compare the classroom climate perceptions of pupils in ASEP classrooms with those of pupils in non-ASEP classrooms.

In analyzing data for classroom climate dimensions as dependent variables, analyses somewhat similar to those reported in Table 4 were employed. August scores on the scales of the *Science Class Inventory* were used as the criterion variables, while instruction (ASEP/control), I_i, seven aptitudinal variables (SES, IQ, sex and four interactions), A_j, and the seven instruction-aptitude interactions, I_iA_j, were used as predictors. It should be noted also that the class aptitude cell was again employed as the unit of statistical analysis and that no pre-test climate data had been collected. Furthermore, because of the absence of pre-test climate information, it is possible that some differences between the climates of ASEP and control classes might have already existed prior to the commencement of the study. Consequently some caution would be needed in interpreting findings from the use of classroom climate as a criterion of instructional effectiveness in the present study.

Results. The first column of figures in Table 5 shows the percentage of variance accounted for in each of the nine classroom climate criteria by the full 15-term regression model. The next three columns of numbers in the table show how the variance of the full model can be partitioned using Overall and Spiegel's Method 2 into independent contributions made by I_i, A_j and I_iA_j variables. The last four columns of Table 5 contain the percentages of variance uniquely accounted for by individual predictors which satisfied conditions (related to the significance of blocks of variables) similar to those outlined in relation to Table 4 and for which the hypothesis of no relation between an individual predictor and a climate scale could be rejected as the alpha = 0.05 level.

TABLE 5

Percentage of variance in each Classroom Climate dimension explained by the full regression model, instruction (I_i), seven aptitudinal variables (A_j) and seven instruction-aptitude interactions (I_iA_j)

R^2(%) Criterion	Full Model	I_i	Blocks of Predictors		Significant Individual Predictors			
			A_j	I_iA_j	SES	IQ	Sex	Interactions
Diversity	11.4	0.1	5.5	5.7				
Speed	15.0	1.0	8.9*	4.7		L 5.7*		2.4*(IQ × sex)
Environment	9.5	A2.5*	3.1	4.0				
Goal Direction	7.2	0.1	6.2	0.6				
Satisfaction	11.4	A4.7**	3.5	3.0				
Disorganization	7.4	0.1	6.3	0.9				
Difficulty	19.0	1.8	13.5**	2.9		L10.1***		
Competitiveness	11.8	1.8	7.3(.1)	2.1		L 4.6**		
Individualization	19.1	A8.7***	8.4*	2.0		L 4.8**		
Median R^2	11.4	1.8	6.3	2.9	0.3	3.8	0.5	0.1

(.1) $p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$

A Higher climate scores associated with ASEP

L Higher climate scores associated with lower IQ

Full regression model contains 15 terms: I_i, 7 A_j variables (SES, IQ, sex, 4 interactions) and 7 I_iA_j interactions.

The results shown in Table 5 indicate that ASEP pupils perceived their classes significantly differently from the way control pupils perceived their classes along three of the climate dimensions. It was found that ASEP pupils perceived their classes as being characterized by a better environment, more satisfaction and more individualization than control pupils perceived their classes. Table 5 also shows that the A_j block independently accounted for a median of 6.3 per cent of variance in climate dimensions, while the instructional variable accounted for a median of 1.8 per cent and the I_iA_j block accounted for a median of 2.9 per cent. The results for individual predictors in Table 5 also indicate that pupil IQ was significantly related to perceptions of *Speed, Difficulty, Competitiveness* and *Individualization*. It was found that pupils of higher IQ tended to perceive their classrooms as being less speeded, less difficult, less competitive and less individualized than did pupils of lower IQ in the same classrooms. The only significant interaction which emerged was an IQ x sex interaction for the *Speed* scale. Inspection of a plot of predicted scores indicated that, while girls' perceptions of the speed in their classrooms were almost independent of IQ, boys' perceptions of speed in the same classrooms decreased with increasing IQ.

Summary and conclusion

The present study has reported the use of a set of nine classroom climate dimensions both as predictor and criterion variables in research related to ASEP. When the climate dimensions were employed as independent variables, it was found that the climate variables contributed an appreciable amount to the variance explained in various learning outcomes over and above that explained by instructional and aptitudinal variables alone. When the climate measures were employed as dependent variables, it was found that ASEP and control pupils had significantly different perceptions of their classrooms along a number of the classroom dimensions.

References

ANDERSON, G.J. "Effects of classroom social climate on individual learning." *American Educational Research Journal*, **2**: 135-152, 1970.

ANDERSON, G.J. *The assessment of learning environments: A manual for the Learning Environment Inventory and the My Class Inventory*. Atlantic Institute of Education, Halifax, 1971.

ANDERSON, G.J. & WALBERG, H.J. "Classroom climate and group learning." *International Journal of the Educational Sciences*, **2**: 175-180, 1968.

ANDERSON, G.J. & WALBERG, H.J. "Learning environments", in H.J. Walberg (Ed.), *Evaluating educational performance: A sourcebook of methods, instruments and examples*, McCutchan, Berkeley, 81-98, 1974.

ASEP (Australian Science Education Project). *Unit 401: A guide to ASEP*. Melbourne, 1974.

COLEMAN, J.S. *Equality of educational opportunity*. U.S. Department of Health, Education and Welfare, 1966.

FRASER, B.J. "Selecting evaluation instruments." *Research in Science Education*, **4**: 99-111, 1974.

FRASER, B.J. "The impact of ASEP on pupil learning and classroom climate." *Research in Science Education*, **5**: 1-12, 1975.

GROBMAN, H. *Evaluation activities of curriculum projects: A starting point.* AERA Monograph Series on Curriculum Evaluation 2, Rand McNally, Chicago, 1968.

HEMPHILL, J.K. *Group dimensions: A manual for their measurement.* Ohio State University Press, Columbus, 1956.

HEMPHILL, J.K. & WESTIE, C.M. "The measurement of group dimensions." *Journal of Psychology*, **29**: 325-342, 1950.

McARTHUR, J.T., WEST, L.H.T. & FRASER, B.J. "Some issues in the simulation of ANOVA by multiple regression techniques." *Research in Science Education*, **5**: 199-207, 1975.

NORTHFIELD, J.R. "The effect of varying the mode of presentation of ASEP materials on pupils' perception of the science curriculum." *Research in Science Education*, **6**, 1976.

OVERALL, J. E. & SPIEGEL, D.K. "Concerning least squares analysis of experimental data." *Psychological Bulletin*, **72**: 311-322, 1969.

POWER, C.N. & SADLER, R. "Non-linear relationships between measures of classroom environment and outcomes in ASEP classrooms." *Research in Science Education*, **6**, 1976.

POWER, C.N. & TISHER, R.P. "Variations in the environment of self-paced science classrooms: Their nature, determinants and effects." A paper presented to the annual conference of the Australia Association for Research in Education, Adelaide, November, 1975.

RANDHAWA, B.S. & FU, L.W. "Assessment and effect of some classroom environment variables." *Review of Educational Research*, **43**: 303-321, 1973.

WALBERG, H.J. "Teacher personality and classroom climate." *Psychology in the Schools*, **5**: 163-169, 1968.

WALBERG, H.J. "The social environment as a mediator of classroom learning." *Journal of Educational Psychology*, **60**: 443-448, 1969(a).

WALBERG, H.J. "Predicting class learning: An approach to the class as a social system." *American Educational Research Journal*, **6**: 529-542, 1969(b).

WALBERG, H.J. "A model for research on instruction." *School Review*, **78**: 185-200, 1970.

WALBERG, H.J. & AHLGREN, A. "Predictors of the social environment of learning." *American Educational Research Journal*, **7**: 153-167, 1970.

WALBERG, H.J. & ANDERSON, G.J. "Classroom climate and individual learning." *Journal of Educational Psychology*, **59**: 414-419, 1968(a).

WALBERG, H.J. & ANDERSON, G.J. "The achievement-creativity dimension and classroom climate." *Journal of Creative Behavior*, **2**: 281-291, 1968(b).

WELCH, W.W. "Curriculum evaluation." *Review of Educational Research*, **39**: 429-443, 1969.

WELCH, W.W. & WALBERG, H.J. "A national experiment in curriculum evaluation." *American Educational Research Journal*, **9**: 373-383, 1972.

VICTORIAN STUDENTS : WHAT HAPPENS TO THEM AFTER HIGHER SCHOOL CERTIFICATE?

R. Lewis

The issue of what happens to Australian students after they have completed their final year of secondary schooling has been investigated on a number of occasions, resulting in accurate estimations of the numbers of school leavers pursuing full time education and the type of education they pursue. Comprehensive data for Australia overall has been presented on at least two occasions (Radford, 1962; Radford and Wilkes, 1975). These reports have described the type of institution attended and course undertaken by students after leaving secondary school. Additional information has been provided on the proportion of Canberra/Queanbeyan school leavers who engaged in full or part time education and the institutions at which this education took place (Australian Department of Education and Science, 1970).

Despite the extensive nature of these reports, particularly those of Radford (1962) and Radford and Wilkes (1975), none has attempted any analysis of the relationships between student variables and institution attended or course undertaken, other than that provided by two or three-way tables. Radford and Wilkes, for example, provide a Table of the proportion of males and females, with fathers of various occupational levels, who entered different professions or institutions of learning. However with n predictors for a criterion variable there are n(n - 1) (n - 2) possible three-way tables to be considered. Clearly investigations along these lines are laborious.

In order to further unravel relationships between selected student variables and what students do after their final year of secondary schooling, it was considered necessary to utilize some statistical procedure which could effectively identify the most important predictors of those selected and then indicate the effect of these, in combination with others. The procedure employed in this analysis was that provided by the OSIRIS program THAID (Morgan and Messenger, 1973).

Description of THAID

THAID provides an efficient and effective means for examining a large set of alternative models which have potential for simplifying and summarising relationships between categories associated with a dependent variable and other variables chosen as predictors. The manner in which it does this is to partition a set of data by a sequence of binary divisions, each of which produces two subgroups from a parent group in such a way that differences in proportions in the dependent variable categories are maximised for that split. The output is a set of mutually exclusive subgroups, characterised by one to four independent attributes, whose dependent variable distributions are maximally different.

Example usage of THAID. Although the program has not been used extensively within Australia it has proved extremely beneficial elsewhere, for example, in the analysis of data from *Five Thousand American Families* (Morgan, 1974) which examined determinants of the economic fortunes of families in the United States. One example of its use in this study was a determination of the predictive ability of a number of variables on whether a person living within two miles of his place of employment walked, drove, or used public transport to travel to work. Application of THAID demonstrated that of the 14 predictors considered, 'City size' was the most important. In cities of less than 500,000 people, 78% drove, 1% used public transport and 21% walked, whereas in larger cities 39% drove, 17% used public transport and 44% walked. The most important factor associated with the proportion of the population using the different means of transport in the smaller cities was income, whereas in the larger cities it was sex. In these analyses THAID was found to be an efficient means of sorting and sifting data, particularly where the predictors were interrelated and interacted with each other.

Sample

The data analysed in this investigation were taken from the sample of secondary students who participated, during 1970, in a survey of achievement in science in Australia, and who were, at that time, in their final year of secondary schooling. Australia was one of 22 countries which participated in the series of surveys conducted by the International Association for the Evaluation of Educational Achievement (IEA). The Australian Council for Educational Research (ACER) was the National Centre responsible for compiling Australian data. The sample of 854 Victorian students under survey in this study represent only part of the total Australian sample of 4201 students from 194 schools about whom data are held on file in the I.E.A. data bank at ACER. The Victorian schools sampled in this study were selected with a probability proportional to size and the sampling stratified by school type and location. Students were selected at random from within each school and the sample of students can be considered to be representative of Victorian students in their final year of secondary schooling in 1970. The further interrogation of this sample in 1972 was undertaken by M. Rosier and K. Ross as part of a follow-up study. The information collected in the follow-up study has provided the criterion measures examined in this report.

Variables

In total, 22 variables were considered as predictors of each of three criterion variables. The criteria were:

(1) the amount of time devoted to further education;
(2) the field of study undertaken by those students continuing with full time study after completion of their Higher School Certificate year;
(3) the type of educational institution attended by these full time students.

The predictors were considered as belonging to one of three categories:

(1) family background variables;
(2) attitudinal variables;
(3) achievement variables.

Criterion variables.

1. *Time spent studying.* This variable was coded into three categories. Persons were considered to be studying full time, part time or not at all. However, for the purposes of this study, which primarily focusses on the characteristics of full time students, non respond-

ents were grouped in the 'No study' category[1] and nurses were considered as full time students. Of the 854 students sampled, 461 were classified as full time students, 87 as part time students and the remaining 316 were considered non-students.

2. *Field of study.* The administrators of the IEA Survey coded subject matter studied (field of study) by applying the International Standardised Classification of Education coding systems (I.S.C.E.D.). Its application in the Australian context provided 24 categories. However, after consideration of the number of Victorian secondary students within each category it was decided to collapse the number of categories to the eight described in Table 1. Where combined categories have been formed, the number of students in each of the simpler categories has also been recorded.
3. *Institution attended.* This variable was initially coded into nine categories. However, after inspection of the numbers of students in full time attendance at each type of institution several categories were combined. The five resulting categories are recorded in Table 2 together with the numbers of students in each of the categories and sub-categories.

TABLE 1

Number of full time post secondary students in different fields of study

Category		Number of students
1. EDUCATION		94
2. ARTS/HUMANITIES		71
Fine and Applied Arts	(12)	
Humanities	(57)	
Social and Behavioural Sciences	(2)	
3. COMMERCIAL/BUSINESS STUDIES		39
4. LAW/JURISPRUDENCE		16
5. SCIENCE/MATHEMATICS		54
Natural Science	(50)	
Maths and Computer Science	(4)	
6. MEDICAL AND PARAMEDICAL		56
7. ENGINEERING/ARCHITECTURE		46
Engineering	(40)	
Architecture and Town Planning	(6)	
8. AGRICULTURE		10
TOTAL		386

---

[1] Figures obtained from the V.U.S.E.B. indicated that approximately 31% of the students completing HSC in 1970 did not attend tertiary educational institutions or repeat HSC. Thus the 37% in the 'No study' category appears accurate, despite the inclusion of non respondents.

TABLE 2

Numbers of full time students in different institutions

Category	Number of students
1. UNIVERSITY	186
2. COLLEGE OF ADVANCED EDUCATION	82
3. TEACHERS COLLEGE	91
4. TECHNICAL AND FURTHER EDUCATION	
Evening College (0)	
Trade School (0)	
Business College (9)	
Nursing/Hospital Training (19)	
Technical College (0)	
Other (2)	
5. SECONDARY SCHOOL	72
TOTAL	461*

* This total is 78 larger than the Total in Table 1. The difference is principally due to the exclusion of secondary repeaters (category 5) from the total in Table 1.

Predictor variables

1. *Family background variables.* The first 'block' of predictors included the family background or 'structural' variables which follow. Beside each variable are recorded some details of the scale used for measurement.

Variable	Details
Student Sex	Two categories
Father's Education	Five cagegories (0 to $\geqslant$ 15 years)
Mother's Education	Five categories (0 to $\geqslant$ 15 years)
Family Size	Five categories (1 to $\geqslant$ 5 children)
Father's Occupation	Six categories[2]

2; *Achievement variables.* The second block of predictors included the scores on a variety of achievement tests. The tests used were the four CSSE (fourth-form Commonwealth Scholarship tests) plus a composite score, the HSC Physics, Chemistry, Biology and English examinations and two IEA administered tests. These last two measures were the IEA Word Knowledge test, which was a 40 item test of vocabulary and the IEA Science test which was an achievement test in Science of 60 items containing sub-tests in Physics, Chemistry, Biology and practical work. Eight intervals of test scores were used to define categories for all these tests except HSC English for which two categories (Pass/Fail) were used and Word

---

[2] Father's Occupation was coded according to the six category system produced by Broom, Jones and Zubrzycki (1968), but with a reversal of the order of the categories.

Knowledge which was divided into six score intervals. One of the eight score categories for the HSC and CSSE tests contained students who did not sit for the examination. This category was coded 0.

3. *Attitudinal variables.* The third and final block of predictors included attitudinal measures selected from those administered during the IEA testing program. The form of these tests can be found in the IEA Data Bank Manual (Schwille and Marshall, 1975). The variables selected are listed below, followed in parentheses by the number of items and coding categories.

(1) Liking for School: This scale assessed the students' attitudes to school life and school learning (12 items, 8 categories).

(2) School Motivation: This was a measure of the strength of the students' motivation towards success in school (11 items, 6 categories).

(3) View of Science in the World: On this Likert type scale a high score meant seeing Science as beneficial to mankind and low score meant that Science was seen as detrimental and restrictive to thinking (6 items, 6 categories).

(4) Importance of Mathematics: This measure was provided by a single item which inquired about the student's view of the importance of a knowledge of Mathematics for the study of Science (5 categories).

(5) Interest in Science: This index was constructed from two types of items. The four items in one group were of a Likert type, using three response categories, to assess an interest in Science. The other group contained eleven items which were concerned with the frequency with which the student undertook certain activities related to an interest in Science (8 categories).

(6) Expected Occupation (6 categories[3]).

(7) Expected Education (5 categories[4]).

Results

As a first step 'in clarifying' which post secondary students continued with full time study, Table 3 was constructed showing:

(1) the percentage of males and females engaged in full time study;

(2) the classification of students by the level of their Father's Occupation.

The sex of full time students is evenly distributed, but when the father's occupational levels are considered, a bias is evident towards the upper levels. The proportion of students from the occupational levels classified as upper and lower professional, and managerial (5 and 6) not only skews the distribution but the bias is further exaggerated when one considers the proportion of the population that falls into levels 5 and 6, particularly the professional in level 6.

To initiate the investigation of the type of institution attended by students studying full time, father's level of occupation and student sex were examined against the type of institution attended (refer to Table 2 for the definition of categories).

---

[3] Ibid 2.

[4] Refer to Father's Education.

TABLE 3

Full time students classified by sex and father's occupation

Full time Students	Sex		Father's Occupation Level						Total
	Male	Female	1	2	3	4	5	6	
%	50	50	7	6	7	15	38	27	100
N	224	225	32	28	31	68	170	120	449

The results (Table 4) indicate that males represent the majority of the intake of most of the institutions defined, apart from Teachers Colleges and the group of institutions labelled TAFE, where the females dominate. The type or level of parental occupation does not appear to influence greatly the percentages of students in attendance at the different institutions, expressed as a proportion of the occupational group continuing with further education. There are, however, some exceptions. Whereas for most categories of *Father's Occupation* there are approximately two students at University for every one at Teachers College, the ratio for students whose father's occupation can be described as semi-skilled workers is one to one, and for professional workers is four to one.

The overall picture suggests that although children of parents who occupy low status jobs are less likely to pursue full time post secondary study, those who continue do not distribute themselves into institutions in any way that can be characterised by the occupational level of their fathers. The only study pattern apparently related to occupational level is attendance at Secondary School; where a greater percentage of children of 'white collar' workers repeat their HSC year than do 'blue collar' worker's children.

TABLE 4

Institution attended by sex and father's occupation

Percentages recorded	Sex			Father's Occupation Level					
Type of Institution	Male	Female	Total	1	2	3	4	5	6
University	58	42	100	41	29	48	40	41	41
CAE	64	36	100	25	18	16	14	17	21
Teachers College	17	83	100	22	29	29	20	23	11
TAFE	26	74	100	9	9	0	5	5	9
Secondary School	67	33	100	3	14	7	22	15	19
TOTAL*	50	50	100	100	100	100	100	100	100

* Note: Discrepancies are due to cumulative rounding error.

THAID

Time Spent at Study. The first use of THAID aimed at determining which of the predictor variables, within each of the three blocks, were most highly related to 'Time spent at study.' The 'splitting' process was continued either until one of the groups produced by the split contained less than 40 persons or four successive splits had occurred (the maximum performed by the program). The first block of predictors analysed were the Background variables. The splits that occurred are shown in Figure 1, which presents the THAID 'Tree'. For each group created by a split, the figure records an identification number for the group, the number of people in the group, the percentages engaged in full time, part time or no study and the predictor value at which the split occurred.

Family Background variables. The pattern of Figure 1 indicates that of the background variables, the one most able to separate the proportion of persons in the full time, part time or no study categories was *Family Size.* This split produced Group 2 which, in turn, split on sex and Group 3 which split on *Father's Occupation.*

The overall trend in families with three or less children is for female full time students to have mothers with 10 years or less formal education and fathers with other than professional occupational status. Males from families of three or less children who are engaged in full time study tend to have fathers who occupy white collar jobs but have 10 years or less formal education. The trend for larger families was quite different (particularly with respect to the girls), and appears more consistent with the figures in Table 3. To appreciate the trends for females (and to some extent males) from smaller families it is necessary to recall that the sample consists of students who have completed their HSC year. Therefore students in the sample who have parents with low educational and occupational levels represent a biased group and their presence may indicate a very high parental aspirational factor which, when combined with the decreased economic strains of a smaller family, result in the large proportional attendance in full time secondary education. It is interesting to note that the group for which the proportion of full time students was greatest is Group 14, which can be described as females whose fathers are not employed in the upper professional ranks and whose mothers have 10 years or less of formal schooling. It is also interesting that this group represents approximately 15% of the sample. Clearly, consideration of who continues to study is a complex question, requiring techniques extending beyond 2 or 3 way tables.

Achievement variables. Before attempting an interpretation of Figure 2, it is necessary to reemphasize that students who did not engage in HSC or CSSE subjects were coded zero. Therefore students who did not study these subjects will, as a result of some analyses, occasionally be grouped with low performers. The THAID tree in Figure 2 indicates that the CSSE, HSC physics examination and HSC chemistry examination are most highly related to *Time Spent at Study*. The group with the largest percentage of full time students was Group 15. Ninety one per cent of this group, characterized by students who performed well on CSSE, HSC physics and HSC chemistry, continued with full time study. In contrast, Group 16, which consists of students who did not sit for the CSSE, achieved less than 53% in HSC chemistry or did not study the subject and were in the lower 67% of students on the IEA word knowledge test, contains only 25% of students who continued to study full time.

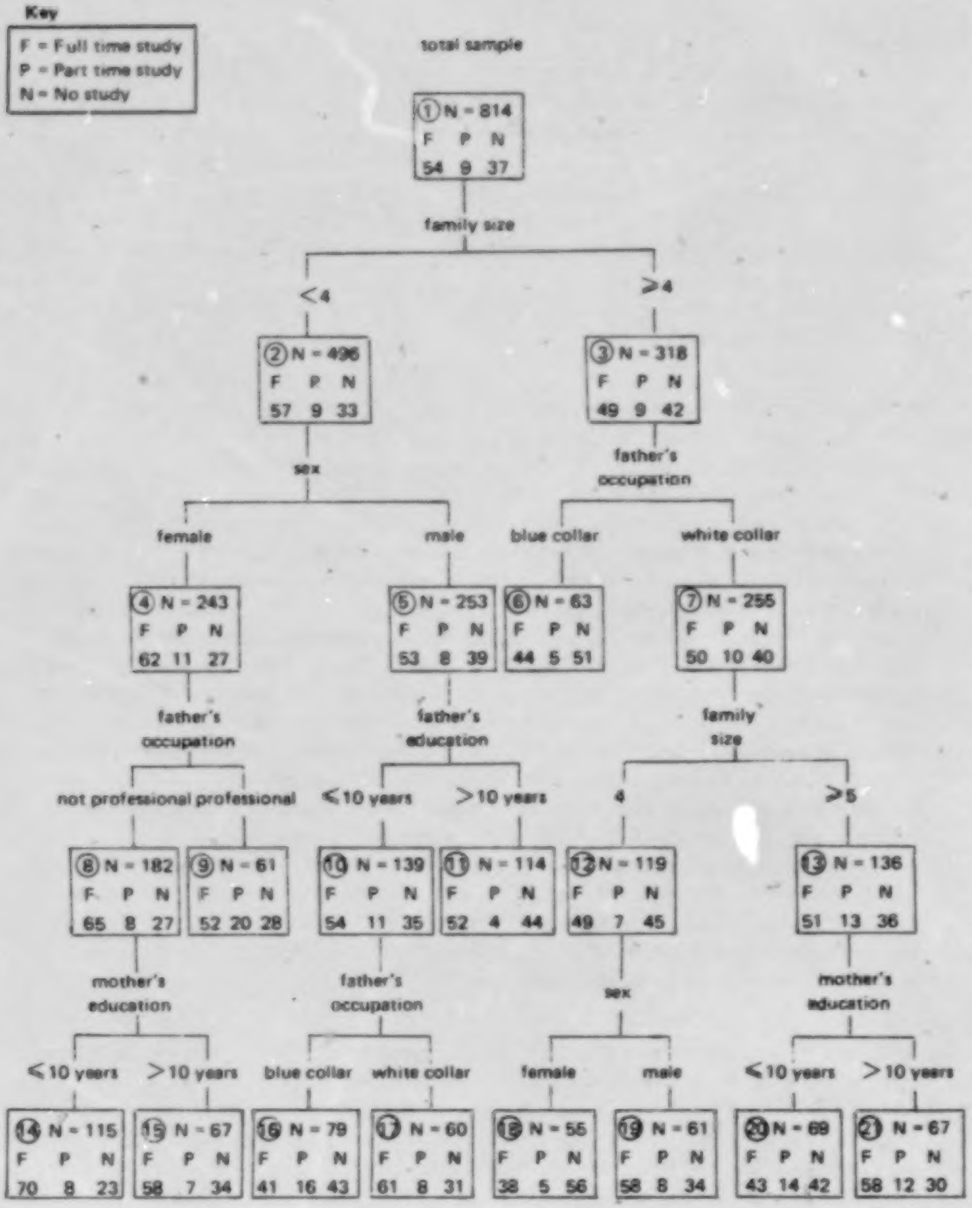
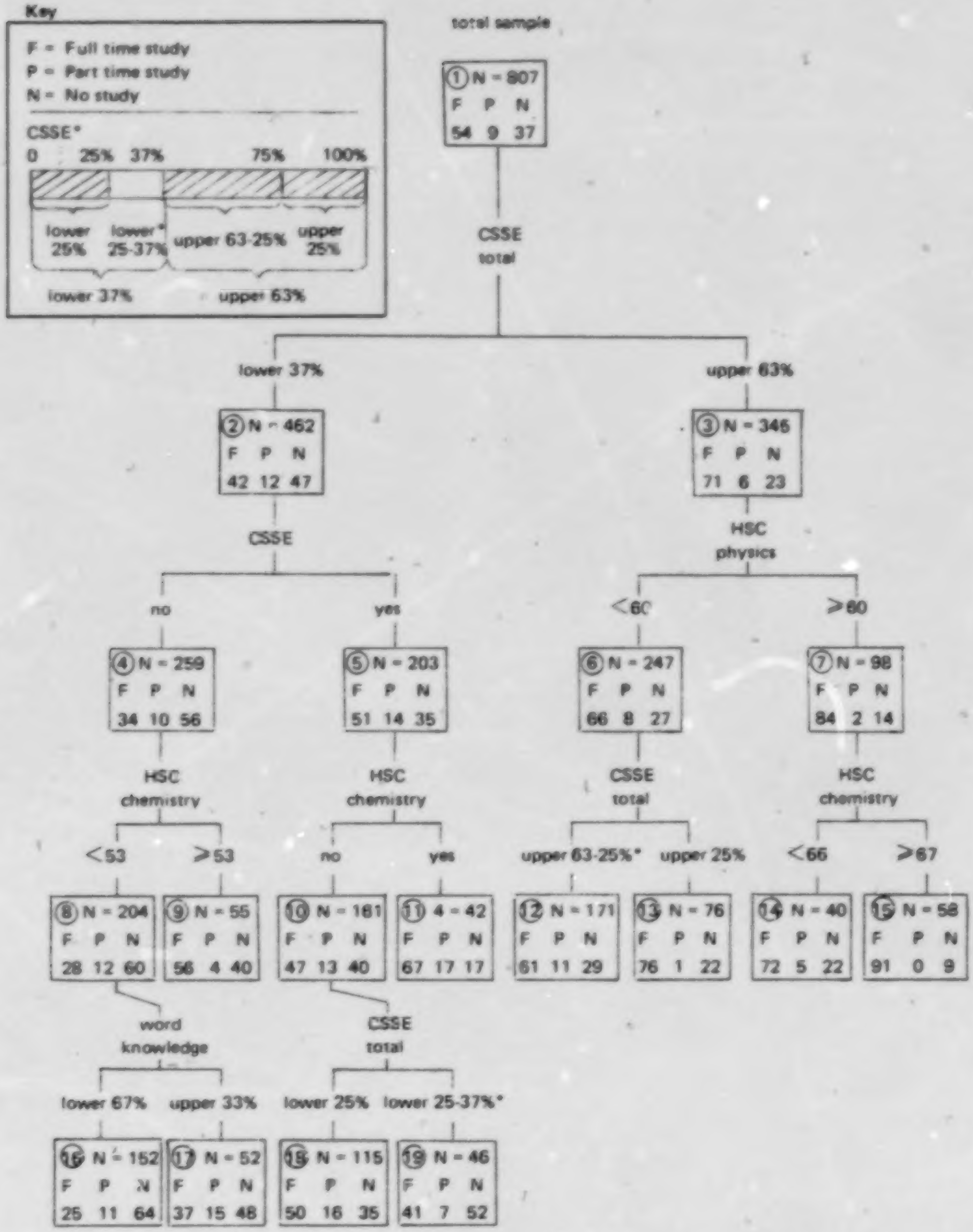

Key
F = Full time study
P = Part time study
N = No study
total sample
① N = 814 F P N 54 9 37
family size
<4
>4
② N = 496 F P N 57 9 33
③ N = 318 F P N 49 9 42
sex
father's occupation
female
male
blue collar
white collar
④ N = 243 F P N 62 11 27
⑤ N = 253 F P N 53 8 39
⑥ N = 63 F P N 44 5 51
⑦ N = 255 F P N 50 10 40
father's occupation
father's education
family size
not professional
professional
≤10 years
>10 years
4
>5
⑧ N = 182 F P N 65 8 27
⑨ N = 61 F P N 52 20 28
⑩ N = 139 F P N 54 11 35
⑪ N = 114 F P N 52 4 44
⑫ N = 119 F P N 49 7 45
⑬ N = 136 F P N 51 13 36
mother's education
father's occupation
sex
mother's education
≤10 years
>10 years
blue collar
white collar
female
male
≤10 years
>10 years
⑭ N = 115 F P N 70 8 23
⑮ N = 67 F P N 58 7 34
⑯ N = 79 F P N 41 16 43
⑰ N = 60 F P N 61 8 31
⑱ N = 55 F P N 38 5 56
⑲ N = 61 F P N 58 8 34
⑳ N = 69 F P N 43 14 42
㉑ N = 67 F P N 58 12 30

FIGURE 1. THAID Analysis: Family background variables as predictors of *Time of Study*


Key
F = Full time study
P = Part time study
N = No study
CSSE*
0
25%
37%
75%
100%
lower 25%
lower* 25-37%
upper 63-25%
upper 25%
lower 37%
upper 63%
total sample
① N = 807
F P N
54 9 37
CSSE total
lower 37%
upper 63%
② N = 462
F P N
42 12 47
③ N = 346
F P N
71 6 23
CSSE
no
yes
HSC physics
<60
>60
④ N = 259
F P N
34 10 56
⑤ N = 203
F P N
51 14 35
⑥ N = 247
F P N
66 8 27
⑦ N = 98
F P N
84 2 14
HSC chemistry
<53
>53
HSC chemistry
no
yes
CSSE total
upper 63-25%*
upper 25%
HSC chemistry
<66
>67
⑧ N = 204
F P N
28 12 60
⑨ N = 55
F P N
56 4 40
⑩ N = 161
F P N
47 13 40
⑪ 4 = 42
F P N
67 17 17
⑫ N = 171
F P N
61 11 29
⑬ N = 76
F P N
76 1 22
⑭ N = 40
F P N
72 5 22
⑮ N = 58
F P N
91 0 9
word knowledge
lower 67%
upper 33%
CSSE total
lower 25%
lower 25-37%*
⑯ N = 152
F P N
25 11 64
⑰ N = 52
F P N
37 15 48
⑱ N = 115
F P N
50 16 35
⑲ N = 46
F P N
41 7 52

Note: All percentages are based on the total HSC sample, and not samples created by 'splits'.

FIGURE 2. THAID Analysis: Achievement variables as predictors of *Time at Study*.

Attitudinal variables. The most important attitude was *Like School* (refer Figure 3). Of those who liked school most, attitudes related to the study of science dominated, in contrast to those who had less liking for school. This latter group split on level of expected education and the school motivation scale. The students most likely to be full time post secondary students had positive attitudes to school and the role of science in the world. The students less likely to continue with full time education had less positive attitudes to school and expected to undergo only two or less years of full time post secondary education. The extent of separation of the proportion of terminal groups (those remaining at the end of the splitting process) studying full time is substantial (21% for Group 4 and 71% for Group 7), and lies between the 25% to 91% range for the achievement variables and the 38% to 70% for background variables.

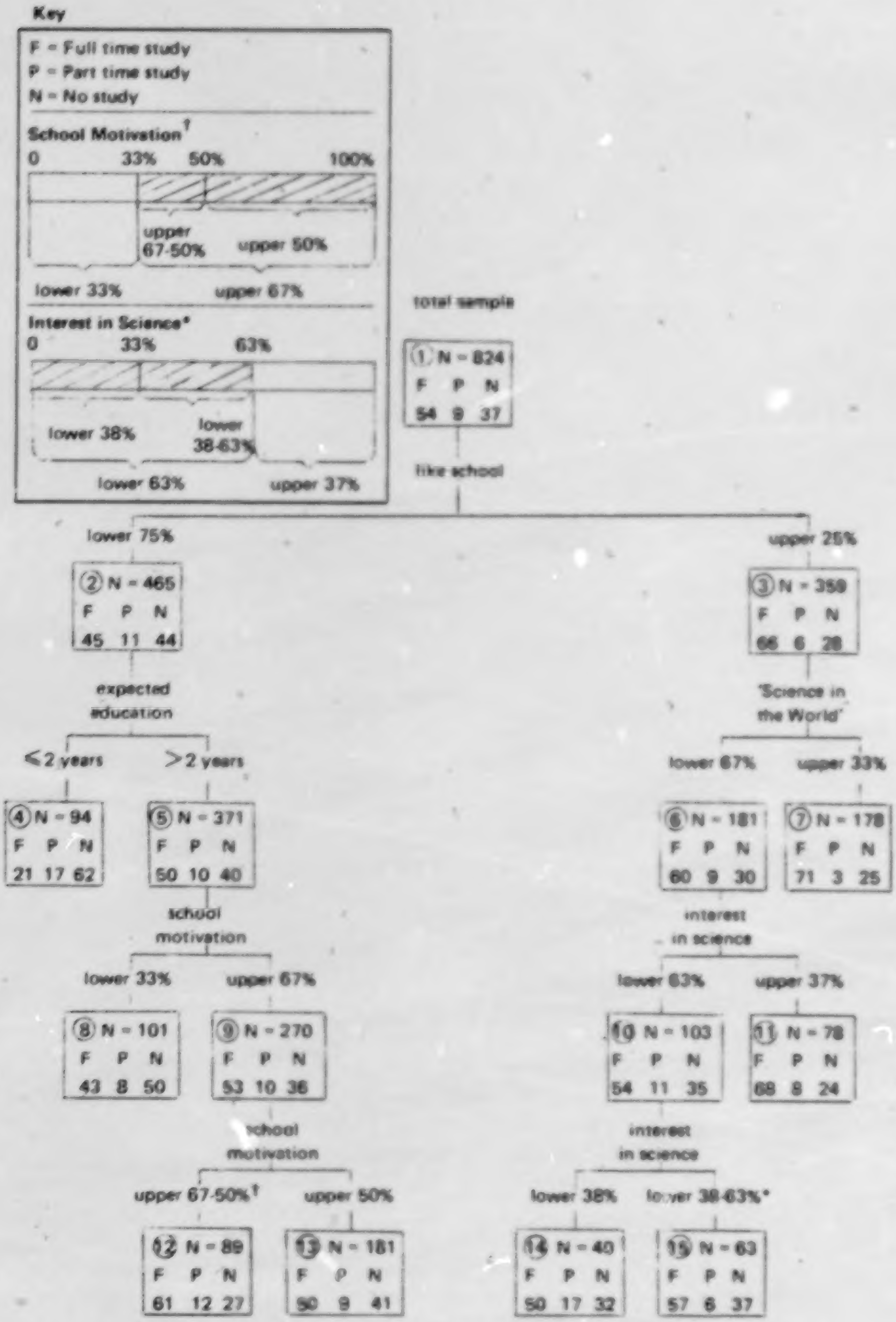
It is necessary to acknowledge that consideration of the three blocks of predictors independently requires caution due to the possibility of predictors from one block influencing relationships between the predictors of another block and the criterion. This could occur, for example, if the students' achievement test scores were related to background variables or attitudes.

Institution attended (full time)

Family background variables. Figure 4 shows the proportion of full time students attending each of the five categories of institutions defined in Table 2. Inspection of the THAID tree indicates that, once again, *Family Size* and *Sex* were crucial factors as they were for *Time Spent at Study*. Similarly, *Father's Educational* and *Occupational Level* were important for female students.

The relative proportions of students at University and Teachers College in Groups 12 and 13 appear to reflect the possible economic difficulties of families, whose head has low educational (and probably occupational) status, which was referred to in earlier discussion. Students in Groups 12 and 13 probably belong to relatively low income families. However the ratio of University students to Teachers College students was 1.6 for Group 12 and 0.4 for Group 13. This difference may suggest since nearly all Teachers College students were subsidised in 1971, that attendance at Teachers College was a more tenable choice than University for students from larger families on relatively low incomes. Although the students' sex had a substantial effect on the ratio, number of students in University to number of students in Teachers College, with the ratio being 11 times greater for males than females, any potential explanation on economic or other grounds would be tenuous. *Family Size*, however, dominated the relationship between male students and attendance at University and with one exception indicates a negative relationship between the two variables.

Achievement variables. The pattern of splits represented in Figure 5 can be best interpreted by reference to the terminal groups. Group 13 indicates that nearly all of the more successful 'straight science' students proceeded to University. This is in contrast to those students who were less successful at physics and chemistry, most of whom either repeated HSC or attended a CAE (Groups 6 and 12). Groups 10 and 11 are characterized by students who failed, or did not attempt HSC chemistry but did study HSC biology (they would probably include a large proportion of females). If, once again, the ratio, number of students at University to number of students at Teachers College is considered, the index values are 0.1 and 1.0 respectively,


Key
F = Full time study
P = Part time study
N = No study
School Motivation†
0
33%
50%
100%
upper 67-50%
upper 50%
lower 33%
upper 67%
Interest in Science*
0
33%
63%
lower 38%
lower 38-63%
lower 63%
upper 37%
total sample
① N = 824
F P N
54 9 37
like school
lower 75%
upper 25%
② N = 465
F P N
45 11 44
③ N = 359
F P N
66 6 28
expected education
<2 years
>2 years
'Science in the World'
lower 67%
upper 33%
④ N = 94
F P N
21 17 62
⑤ N = 371
F P N
50 10 40
⑥ N = 181
F P N
60 9 30
⑦ N = 178
F P N
71 3 25
school motivation
lower 33%
upper 67%
interest in science
lower 63%
upper 37%
⑧ N = 101
F P N
43 8 50
⑨ N = 270
F P N
53 10 36
⑩ N = 103
F P N
54 11 35
⑪ N = 78
F P N
68 8 24
school motivation
upper 67-50%†
upper 50%
interest in science
lower 38%
lower 38-63%*
⑫ N = 89
F P N
61 12 27
⑬ N = 181
F P N
50 9 41
⑭ N = 40
F P N
50 17 32
⑮ N = 63
F P N
57 6 37

Note: All percentages are based on the total HSC sample, and not samples created by 'splits'.

FIGURE 3. THAID Analysis: Attitudinal variables as predictors of *Time of Study*

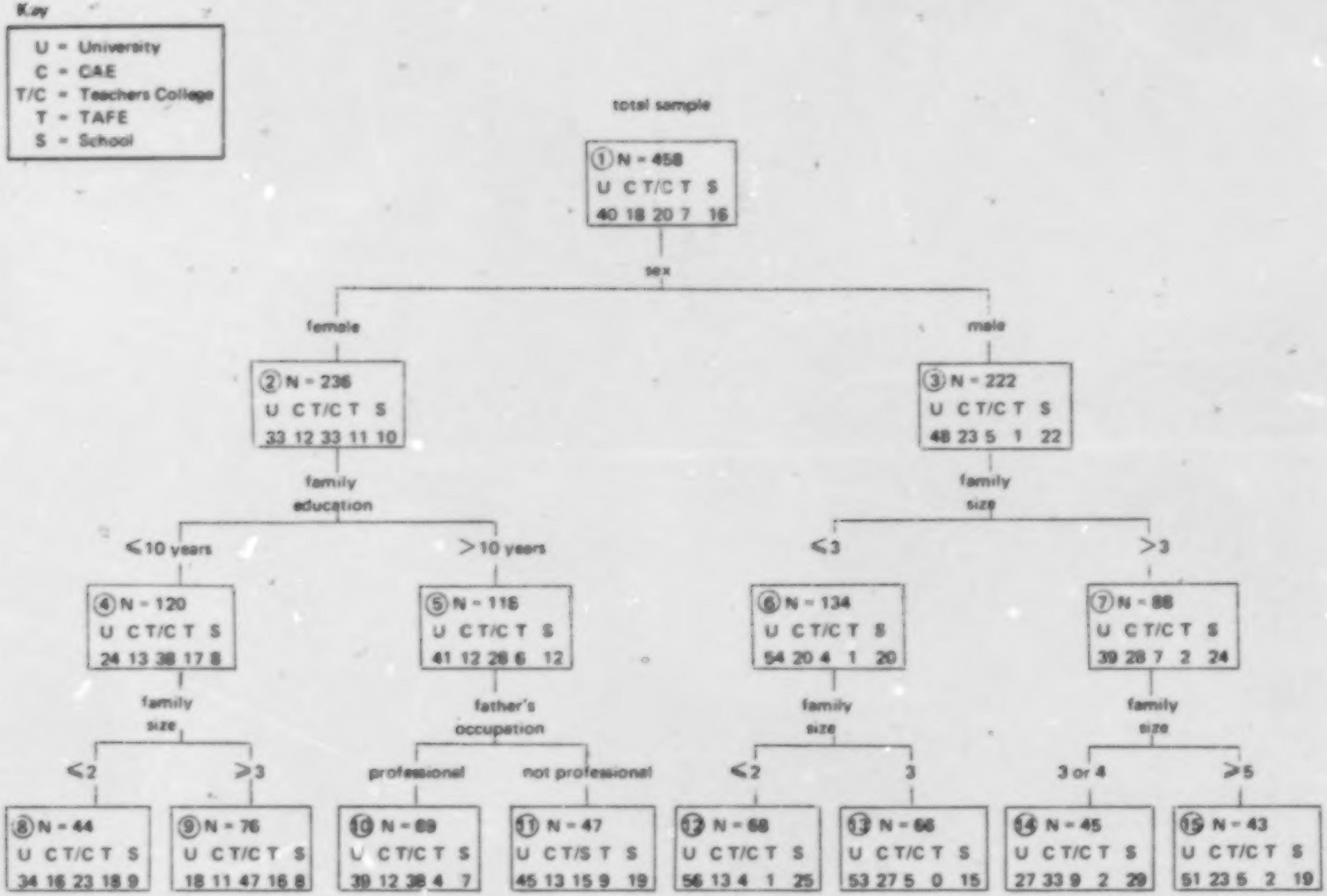

Key
U = University
C = CAE
T/C = Teachers College
T = TAFE
S = School
total sample
① N = 458
U C T/C T S
40 18 20 7 16
sex
female
male
② N = 236
U C T/C T S
33 12 33 11 10
③ N = 222
U C T/C T S
48 23 5 1 22
family education
family size
≤10 years
>10 years
<3
>3
④ N = 120
U C T/C T S
24 13 38 17 8
⑤ N = 116
U C T/C T S
41 12 28 6 12
⑥ N = 134
U C T/C T S
54 20 4 1 20
⑦ N = 88
U C T/C T S
39 28 7 2 24
family size
father's occupation
family size
family size
<2
>3
professional
not professional
<2
3
3 or 4
>5
⑧ N = 44
U C T/C T S
34 16 23 18 9
⑨ N = 76
U C T/C T S
18 11 47 16 8
⑩ N = 69
U C T/C T S
39 12 38 4 7
⑪ N = 47
U C T/S T S
45 13 15 9 19
⑫ N = 68
U C T/C T S
56 13 4 1 25
⑬ N = 66
U C T/C T S
53 27 5 0 15
⑭ N = 45
U C T/C T S
27 33 9 2 29
⑮ N = 43
U C T/C T S
51 23 5 2 19

FIGURE 4. THAID Analysis: Family Background variables as predictors of *Institution Attended*.

depending upon whether the student was above or below the median on CSSE science.

The Terminal Groups 8 and 9 both consisted of students who did not pass or take HSC chemistry and did not study HSC biology. However greater success on the Work Knowledge test was highly related to attendance at University, with the more 'literate' being twice as likely to become University students.

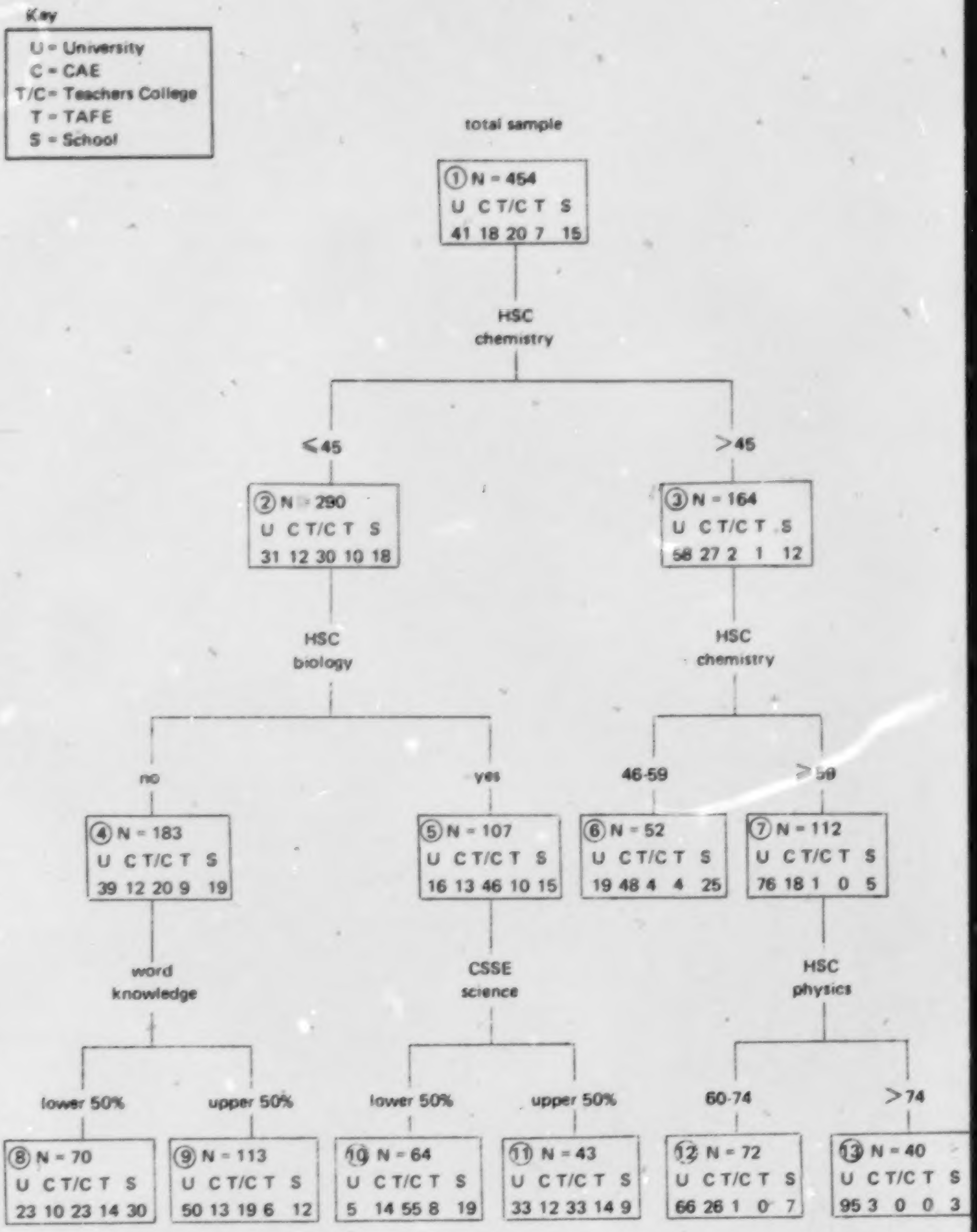
Attitudinal variables. A complex pattern of splits is shown in Figure 6, with six of the seven attitudinal measures being responsible for divisions in the sample. The first split was particularly difficult to interpret as it appears from the distribution of students in Groups 2 and 3 that the split was largely based on the proportion of students at University and Teachers College. The split indicates that a larger proportion of the students at University see Mathematics as an important basis for the study of science but any explanation would be extremely tenuous, for example, this could be due to the larger number of science students at University. Similarly any hope of meaningful generalizations from the patterns in Figure 6 seems equally slight and will therefore be avoided.

Field of study

Background variables. The pattern of results in Figure 7 shows that *Family Size* had far less of a relationship with *Field of Study* than it had with the other two criteria, but *Sex* and *Father's Occupation* maintained significant roles. Inspection of the terminal groups appears the most efficient way of investigating the relationships between predictors and criteria: Group 5 contains the greatest proportion of Medicine/Nursing students, the majority of whom are probably some of the 19 nurses in the sample. The largest proportion of females tended to undertake studies in the field of education as is shown by the distributions of Groups 8, 12 and 13 and the preceding discussion of Figure 4 regarding the students at Teachers Colleges. The only other field of study largely undertaken by females was Humanities. The majority of the remaining female students in medicine, engineering and the sciences have fathers who do not occupy a professional position and come from families with more than two children. However the fathers of the greater percentage of these have had more than ten years formal education.

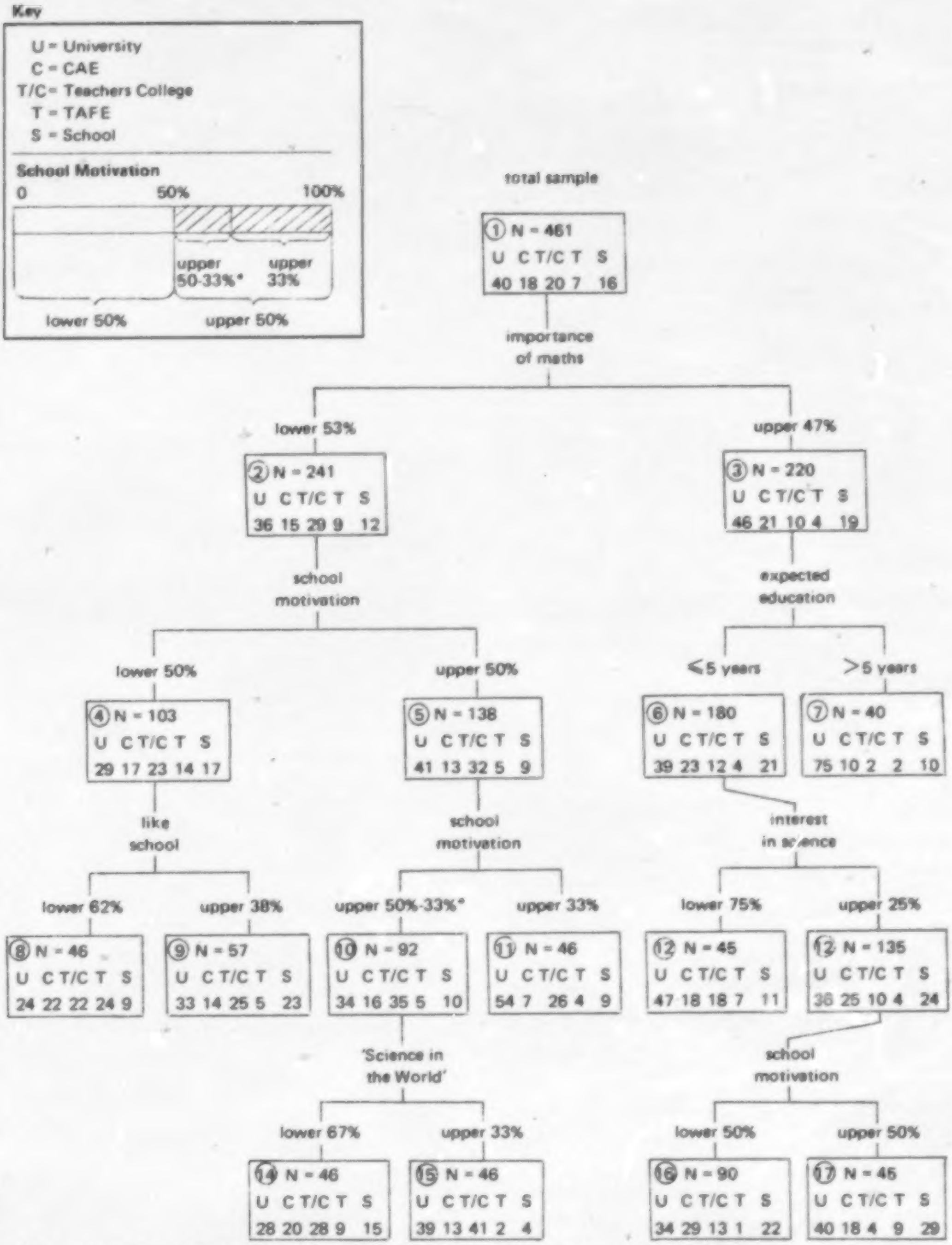
The males in the sample are found in Terminal Groups 7, 10 and 11. Group 7 contains principally students of Science, Engineering and Medicine and is characterized by males with fathers in professional occupational positions. The other group of males who were largely engaged in learning Engineering and Medicine are from families where the father is not in a professional occupation and the mother has 10 years or less of formal education (Group 10). The remaining Terminal Group, Group 11, contains the largest proportion of students undertaking commercial studies although the students distributed themselves relatively evenly among all fields of study.

Achievement variables. The most efficient predictor among the achievement variables, the effects of which are described in Figure 8, is HSC physics which separated the Science, Medicine and Engineering students from those undertaking Education, Humanities and Commercial studies. The only predictor able to separate the ex-physics students in Group 3 was Word Knowledge, a high performance on which tended to distinguish Medical students from the others. For the non physics students in Group 2 the undertaking of HSC biology identified


Key
U = University
C = CAE
T/C = Teachers College
T = TAFE
S = School
total sample
① N = 454
U C T/C T S
41 18 20 7 15
HSC chemistry
≤45
>45
② N = 290
U C T/C T S
31 12 30 10 18
③ N = 164
U C T/C T S
58 27 2 1 12
HSC biology
HSC chemistry
no
yes
46-59
>59
④ N = 183
U C T/C T S
39 12 20 9 19
⑤ N = 107
U C T/C T S
16 13 46 10 15
⑥ N = 52
U C T/C T S
19 48 4 4 25
⑦ N = 112
U C T/C T S
76 18 1 0 5
word knowledge
CSSE science
HSC physics
lower 50%
upper 50%
lower 50%
upper 50%
60-74
>74
⑧ N = 70
U C T/C T S
23 10 23 14 30
⑨ N = 113
U C T/C T S
50 13 19 6 12
⑩ N = 64
U C T/C T S
5 14 55 8 19
⑪ N = 43
U C T/C T S
33 12 33 14 9
⑫ N = 72
U C T/C T S
66 26 1 0 7
⑬ N = 40
U C T/C T S
95 3 0 0 3

Note: All percentages are based on the total HSC sample, and not samples created by 'splits'.

FIGURE 5: THAID Analysis: Achievement variables as predictors of *Institution Attended.*


Key
U = University
C = CAE
T/C = Teachers College
T = TAFE
S = School
School Motivation
0
50%
100%
upper 50-33%*
upper 33%
lower 50%
upper 50%
total sample
① N = 461
U C T/C T S
40 18 20 7 16
importance of maths
lower 53%
upper 47%
② N = 241
U C T/C T S
36 15 29 9 12
③ N = 220
U C T/C T S
46 21 10 4 19
school motivation
expected education
lower 50%
upper 50%
<5 years
>5 years
④ N = 103
U C T/C T S
29 17 23 14 17
⑤ N = 138
U C T/C T S
41 13 32 5 9
⑥ N = 180
U C T/C T S
39 23 12 4 21
⑦ N = 40
U C T/C T S
75 10 2 2 10
like school
school motivation
interest in science
lower 62%
upper 38%
upper 50%-33%*
upper 33%
lower 75%
upper 25%
⑧ N = 46
U C T/C T S
24 22 22 24 9
⑨ N = 57
U C T/C T S
33 14 25 5 23
⑩ N = 92
U C T/C T S
34 16 35 5 10
⑪ N = 46
U C T/C T S
54 7 26 4 9
⑫ N = 45
U C T/C T S
47 18 18 7 11
⑫ N = 135
U C T/C T S
36 25 10 4 24
'Science in the World'
school motivation
lower 67%
upper 33%
lower 50%
upper 50%
⑭ N = 46
U C T/C T S
28 20 28 9 15
⑮ N = 46
U C T/C T S
39 13 41 2 4
⑯ N = 90
U C T/C T S
34 29 13 1 22
⑰ N = 45
U C T/C T S
40 18 4 9 29

Note: All percentages are based on the total HSC sample, and not samples created by 'splits'.

FIGURE 6. THAID Analysis: Attitudinal variables as predictors of *Institution Attended.*

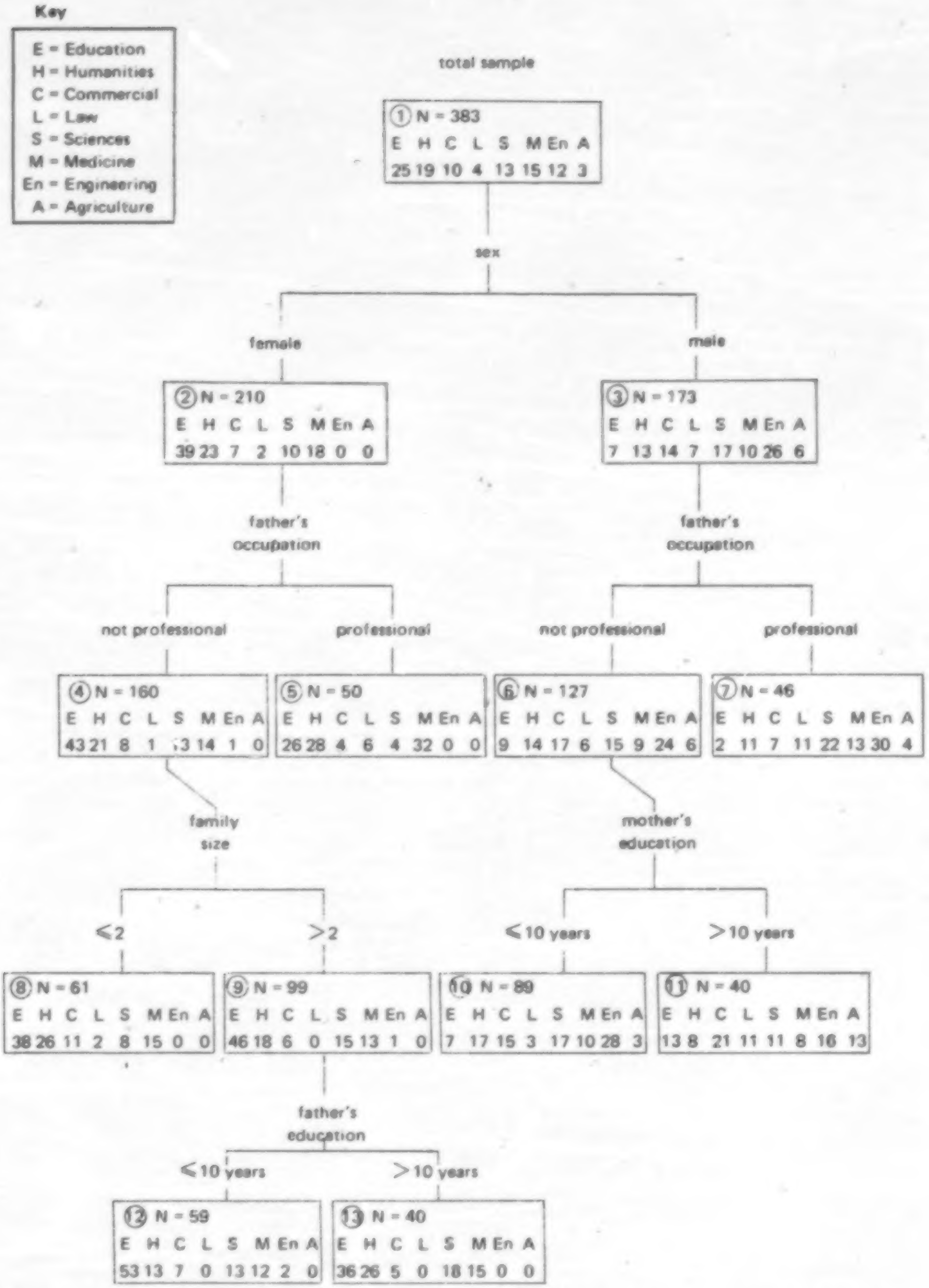
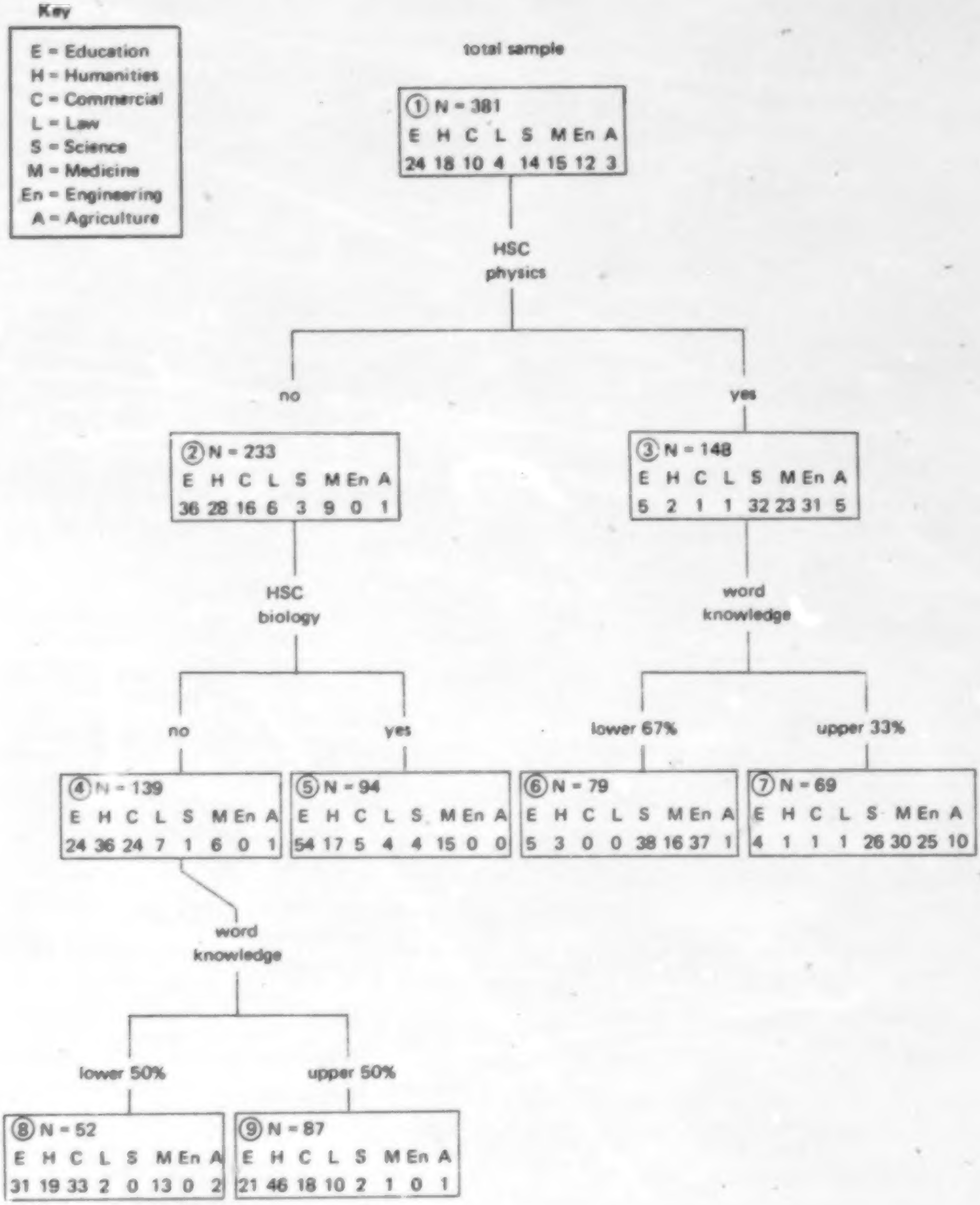

Key
E = Education
H = Humanities
C = Commercial
L = Law
S = Sciences
M = Medicine
En = Engineering
A = Agriculture
total sample
① N = 383
E H C L S M En A
25 19 10 4 13 15 12 3
sex
female
② N = 210
E H C L S M En A
39 23 7 2 10 18 0 0
male
③ N = 173
E H C L S M En A
7 13 14 7 17 10 26 6
father's occupation
not professional
professional
④ N = 160
E H C L S M En A
43 21 8 1 13 14 1 0
⑤ N = 50
E H C L S M En A
26 28 4 6 4 32 0 0
⑥ N = 127
E H C L S M En A
9 14 17 6 15 9 24 6
⑦ N = 46
E H C L S M En A
2 11 7 11 22 13 30 4
family size
≤2
>2
mother's education
≤10 years
>10 years
⑧ N = 61
E H C L S M En A
38 26 11 2 8 15 0 0
⑨ N = 99
E H C L S M En A
46 18 6 0 15 13 1 0
⑩ N = 89
E H C L S M En A
7 17 15 3 17 10 28 3
⑪ N = 40
E H C L S M En A
13 8 21 11 11 8 16 13
father's education
≤10 years
>10 years
⑫ N = 59
E H C L S M En A
53 13 7 0 13 12 2 0
⑬ N = 40
E H C L S M En A
36 26 5 0 18 15 0 0

FIGURE 7. THAID Analysis: Family background variables as predictors of *Field of Study*.

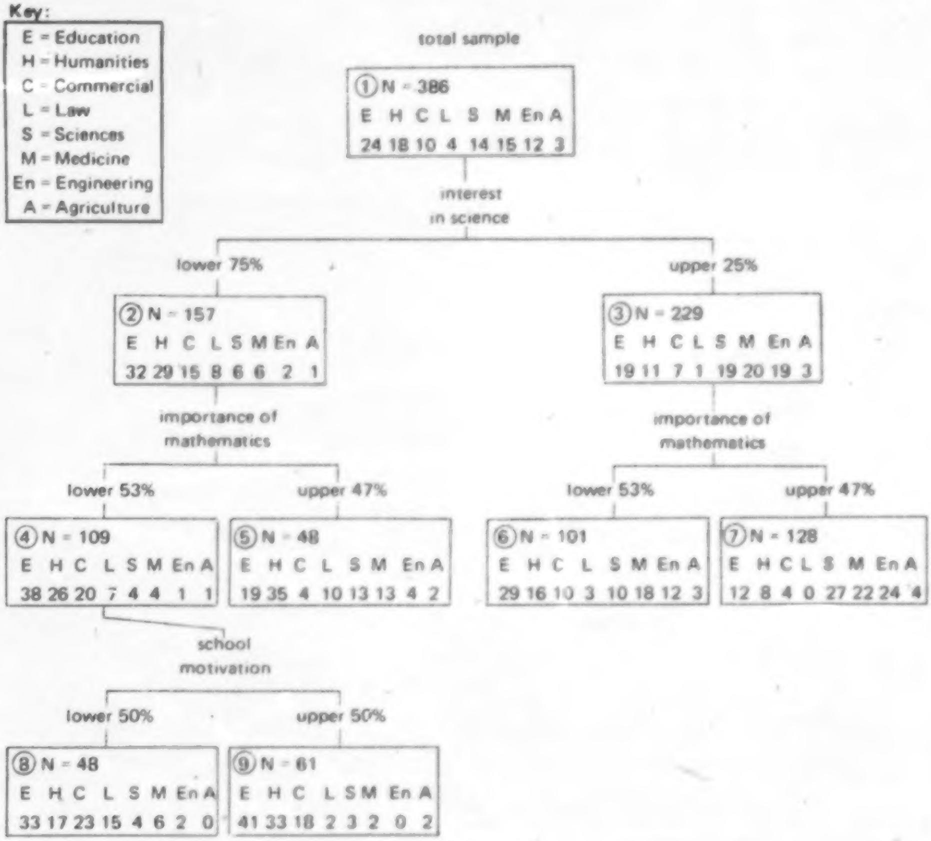

Key
E = Education
H = Humanities
C = Commercial
L = Law
S = Science
M = Medicine
En = Engineering
A = Agriculture
total sample
① N = 381
E H C L S M En A
24 18 10 4 14 15 12 3
HSC physics
no
yes
② N = 233
E H C L S M En A
36 28 16 6 3 9 0 1
③ N = 148
E H C L S M En A
5 2 1 1 32 23 31 5
HSC biology
no
yes
word knowledge
lower 67%
upper 33%
④ N = 139
E H C L S M En A
24 36 24 7 1 6 0 1
⑤ N = 94
E H C L S M En A
54 17 5 4 4 15 0 0
⑥ N = 79
E H C L S M En A
5 3 0 0 38 16 37 1
⑦ N = 69
E H C L S M En A
4 1 1 1 26 30 25 10
word knowledge
lower 50%
upper 50%
⑧ N = 52
E H C L S M En A
31 19 33 2 0 13 0 2
⑨ N = 87
E H C L S M En A
21 46 18 10 2 1 0 1

Note: All percentages are based on the total HSC sample, and not samples created by 'splits'.

FIGURE 8. THAID Analysis: Achievement variables as predictors of *Field of Study.*

potential teachers (Group 5) whereas students who did not do Biology (Group 4) tended to become involved in the study of Humanities and Commercial Studies. The completely non science trained students in Group 4 split into the two terminal groups not yet discussed (Groups 8 and 9). The variable on which the split was based was Word Knowledge a measure of verbal ability, and it created two groups the less able of which contained mainly students of Education and Commercial Studies, while the more able group contained the students of Humanities.

Attitudinal variables. The pattern of splits in Figure 9 which describes the relationships between the attitudinal variables and Field of Study was not as difficult to interpret as were the relationships between attitudes and Institution attended. The attitudes related to science and mathematics distinguished quite clearly and consistently between the science oriented fields of study and others.


Key:
E = Education
H = Humanities
C = Commercial
L = Law
S = Sciences
M = Medicine
En = Engineering
A = Agriculture
total sample
① N = 386
E H C L S M En A
24 18 10 4 14 15 12 3
interest in science
lower 75%
upper 25%
② N = 157
E H C L S M En A
32 29 15 8 6 6 2 1
③ N = 229
E H C L S M En A
19 11 7 1 19 20 19 3
importance of mathematics
importance of mathematics
lower 53%
upper 47%
lower 53%
upper 47%
④ N = 109
E H C L S M En A
38 26 20 7 4 4 1 1
⑤ N = 48
E H C L S M En A
19 35 4 10 13 13 4 2
⑥ N = 101
E H C L S M En A
29 16 10 3 10 18 12 3
⑦ N = 128
E H C L S M En A
12 8 4 0 27 22 24 4
school motivation
lower 50%
upper 50%
⑧ N = 48
E H C L S M En A
33 17 23 15 4 6 2 0
⑨ N = 61
E H C L S M En A
41 33 18 2 3 2 0 2

Note: All percentages are based on the total HSC sample, and not samples created by 'splits'.

FIGURE 9. THAID Analysis: Attitudinal variables as predictors of *Field of Study*.

Summary

An overview of results is unnecessary when data is so clearly presented as to be directly interpretable. A summary of results is particularly inappropriate when one's own interest may influence areas of emphasis and no summary can hope to present a complete description and interpretation of the findings. The fact that the data allow such ready analysis acts as a strong recommendation for the statistical procedure employed. The advantages of THAID therefore are not only related to its ability to identify predictors of most value and consider these in conjunction with up to three other variables but also to present the findings in a meaningful manner.

Acknowledgement

Work on the preparation of this paper was supported in part by a grant from the Education Research and Development Committee of the Australian Government.

References

AUSTRALIAN DEPARTMENT OF EDUCATION AND SCIENCE. "Survey of 1968 school leavers in the Canberra/Queanbeyan area." *Education News,* **12**(*10*), 1970.

BROOM, L., JONES, F.L. & ZUBRZYCKI, J. "Social Stratification in Australia", in J.A. Jackson (Ed.) *Social Stratification. Social Studies.* **1**: 212-233, University Press, Cambridge, 1968.

MORGAN, J.N. (ed.) *Five thousand American families – Patterns of economic progress.* **11** University of Michigan, 1974.

MORGAN, J.N. & MESSENGER, R.C. *THAID A Sequential Analysis Program for the Ana. of Nominal Scale Dependent Variables.* University of Michigan, 1973.

RADFORD, W.C. *School Leavers in Australia 1959-1960.* ACER Series 75, 1962.

RADFORD, W.C. & WILKES, R.E. *School Leavers in Australia 1971-1972.* ACER Series 1975.

SCHWILLE, J. & MARSHALL, S. *The IEA Six-Subject Data Bank: A General Introductio* International Association for the Evaluation of Educational Achievement, Stockh 1975.

THE CONTRIBUTORS

J.E. BUTLER	Lecturer in Education, The University of Queensland.
C.E. ENGEL	Associate Professor of Medicine, Head of Division of Medical Education, University of Newcastle, New South Wales.
R.B. FLANAGAN	Lecturer in Science, Newcastle College of Advanced Education, New South Wales.
BARRY J. FRASER	Lecturer in Education, Macquarie University, New South Wales.
P.L. GARDNER	Reader in Education, Monash University, Victoria.
R. LEWIS	Australian Council of Educational Research, Victoria.
LINDSAY D. MACKAY	Associate Professor of Education, Monash University, Victoria.
I.A. NAPPER	A/Senior Lecturer, Claremont College of Advanced Education, Western Australia.
JEFF R. NORTHFIELD	Lecturer in Education, Monash University, Victoria.
EDWARD E. NUNAN	Lecturer, Salisbury College of Advanced Education, Victoria.
COLIN POWER	Senior Lecturer in Education, The University of Queensland.
ROYCE SADLER	Lecturer in Education, University of Queensland.
L. SCHAFE	ERDC Research Training Fellow, Monash University, Victoria.
U. MYINT THEIN	Research Student (Education), Monash University, Victoria.
RICHARD T. WHITE	Senior Lecturer in Education, Monash University, Victoria.
RAY WATTERSON	Teacher, Education Department, Victoria.